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SOIL WASTAGE

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THE invitation to give thought to the conservation of resources that affect our future, appeals to me with almost personal force, for my studies of the past decade have led to the belief that the era of the earth's future habitability is vastly greater than we have been wont to think. We have grown up in the belief that the earth sprang from chaos at the opening of our era and is plunging on to catastrophe or to a final winter in the near future. Quite at variance with this, I have come to believe that the earth arose from a regenerative process and that it offers a fair prospect of fitness for habitation for tens of millions of years to come. If this be true, it is eminently fit that our race should give a due measure of thought to the ulterior effects of its actions.

It is one of the latest conceptions of geology that climatic conditions have been of the same order as at present from early eras, in the large view, in spite of some notable variations, and that this uniformity is the result of a *profound regulative system* which has sufficed to keep the temperatures of the earth's surface and the constitution of the earth's atmosphere within the narrow range congenial to life for many millions of years. As a result there has been no break in the continuity of land life since it came into being eras ago. It appears, further, that the sources of supply of the vital elements are still adequate, and are likely to be so for long ages, that the regulative system is still in effective control, and that a vast future of habitability may fairly be predicted, subject only to some contingencies of collision or disturbing approach of celestial bodies. Whether you are prepared to accept so large a view of the habitable future or not, I trust you will

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strike hands with me in the conviction that the probabilities of the future are at least so great as to render imperative the serious consideration of our obligations toward it.

It is a familiar geologic deduction that for long eras rains have fallen on the lands and soils have grown in depth, while the surface has been washed away. Soil-production and soil-removal have run hand in hand, and yet they have been so controlled by the adjustments of nature that no large part of the surface has been swept bare enough to altogether exclude vegetation. More than this, it appears that the usual adjustments of nature *make rather for increasing fertility of soil* than depletion. It is true that at intervals deformations of the earth have intervened giving mountainous heights and precipitous surfaces from which the soil-product has been washed faster than it could be produced; and desert conditions have also intervened locally; but these diastrophic effects are perhaps rather rejuvenations necessary to the preservation of the continents than destructive episodes. Whenever such heights and slopes have been raised, the atmosphere and its waters have at once begun to grade them down, to cover them with soil, and to give to them a renewed habitability. So, in these and other ways, the gifts of the great past now present themselves to us as the product of a marvelous system of control which has checked excesses and forced movement toward the golden means in which have lain productivity and congeniality to life. Thus has come our inheritance of a land suitable for habitation, of a soil-mantle of great fertility, of a precipitation conducive to productiveness, and of a system of streams endowed with great possibilities of water-foods, of power and of navigation.

We do not hesitate to enter into the inheritance, but what part shall we take in the regulative system that produced and maintains it? How shall we cooperate with nature in rendering conditions still more serviceable to ourselves, and in transmitting a still greater inheritance for our successors? Clearly we may use the proper revenues of our inheritance, but surely we should not rob our successors of their share in it.

Let us turn at once to the basal factors in the problem, the rainfall, the soil-formation and soil-wastage, the special theme of this hour. The rainfall may be regarded as an inherited asset, the soil is clearly an inherited asset, even a little soil-removal is an advantage, but reckless soil-wastage is a serious error. Soils are the product of the atmosphere and its waters modifying the rock surface. When they have aided the air in producing soil by rock decay, the atmospheric waters may pass either into plants or back to the surface through the soil and out by evaporation, or they may pass on down to the groundwaters and thence into the streams, furnishing there the basis for

water-foods, for power and for navigation. Here is a good work—soil-production—followed by advantageous courses of the water both up and down. On the other hand, the rainfall may rush away on the surface as a foul erosive flood, wasting soil and plant-food, gullying the surface, flooding the valleys, filling the reservoirs, sweeping out the dams, barring the streams and clogging the deltas. If it shall be found that nearly all the rainfall should go into the soil and thence into the under-drainage, coming out slowly and steadily by seepage and by springs into the streams, clear and pure, these streams should present nearly ideal conditions for water-food, for water-power and for stream-navigation. An ideal solution of the soil problem may therefore solve the greater part of the whole complex of problems of which navigation is the last term. It may thus prove to be the *key* problem. It is clearly the *initial problem,* for it attacks the rainfall when it first touches the earth.

To see more definitely if it be the key problem, we must turn to details, and yet, with the brevity that is imperative, we may only look at major details, passing by a multitude of special cases, some of which are even exceptions.

While soils are formed by the atmosphere and its waters acting upon rock (aided by plants and animals), soil surfaces are carried away by wind and wash. At any instant, then, the depth of the soil measures the lag of removal behind production. We hasten to note that the addition of new soil below and the loss of exhausted soil above are alike tributary to permanent fertility, and clearly the best results spring from *the proper ratio* of addition at the bottom, to wastage at the surface.

We have as yet no accurate measure of the rate of soil production. We merely know that it is *very slow.* It varies obviously with the kind of rock. Some of our soils are derived from material already reduced to a finely pulverized condition. Such are the lowland accumulations from highland wash. Such also is the glacial drift, rock-flour rasped from the face of the rock by the glacial file and ground up with old soils. Soils may be developed from such half-prepared material with relative rapidity, but observation shows that even in these cases, when the slope is considerable, wind, wash and cropping remove the surface much too fast for stable fertility. For average rock, under the usual conditions of our climate, the common estimate of natural loss and gain has been a foot in 4,000 to 6,000 years, which includes channel-cutting and bank-undermining. This seems to me too rapid a rate for ordinary soil production under normal conditions. Without any pretensions to a close estimate, I should be unwilling to name a mean rate of soil-formation greater than one foot in 10,000 years, on the basis of observation. If we allow 40,000 years for the

formation of the four feet of soil next to the rock over our average domain, where such depth obtains, it will probably be none too conservative. To preserve a good working soil-depth, with such an estimate, surface wastage should not exceed some such rate as one inch in a thousand years. If one chooses to indulge in a more liberal estimate of the soil-forming rate, it will still appear, under any intelligent estimate, that surface wastage is a serious menace to the retention of our soils under present modes of management. Historical evidence enforces this danger. In the Orient there are large tracts almost absolutely bare of soil now, which formerly bore flourishing populations. Long-tilled lands generally bear testimony of like import. Much more than mere loss of fertility is here menaced; it is *the loss of the soil-body itself,* a loss almost beyond repair. When our soils are gone, we too must go, unless we shall find some way to feed on raw rock or its equivalent. The immense tonnage of soil-material carried out to sea annually by our rivers, even when allowance is made for laudable wash, and for material derived from the river channels, is an impressive warning of the danger of excessive soil-waste. Nor is this all; the wash from one acre often buries the fertile portion of another acre, or of several. Sometimes one's loss is another's gain, but all too frequently one's loss is another's disaster.

If the atmospheric waters may not run off the surface freely without serious menace, where may they go and what may they do consistent with our welfare? The answer lies in a return to the study of the origin and internal work of soils. For necessary brevity, let us neglect all secondary soils, or overplacements, and consider simply the origin and activities of primary soils derived from primary rocks. The action of air and water in producing soil from such rock is partly chemical and partly physical. Certain rock substances are made soluble and become plant food or plant poisons, while others remain relatively insoluble, but are reduced to a finely divided state and form the earthy element of the soil.

Some of the soluble substances thus formed at the base of soils are necessary plant food, while some are harmful; but what is more to the point, all are harmful if too concentrated. There is need, therefore, that enough water pass through the forming soil, and on down to the ground-water and out through the under-drainage, to carry away the excess of these products. An essential part of the best adjustment is thus seen to lie in *a proper apportionment of the amount of water which goes through the soils.* If this be not enough, the plants will suffer from saline excess; if it be too much, the plants may suffer from saline deficiency.

When evaporation from the surface is active and prolonged, waters which had previously gone down to the zone of soil-formation and

taken up soluble matter, may rise again to the surface bringing the soluble matter up and leaving it at the surface on evaporation. Up to a certain point this is favorable to the plant; beyond the critical point, it begins to be harmful, as abundantly shown in the "alkaline" efflorescences of arid regions.

Besides the water that goes through the soil into the subdrainage, and that which runs off on the surface, enough must be held *at all times in the soil during the growing season* to supply the plants, and yet not enough to water-log the soil.

Here, then, are a series of possible excesses and deficiencies, between which lie the golden means which give best results. The problem of soil-management thus appears to be a problem of proper balancings and adjustments.

The key to the problem lies in due control of the water which falls on each acre. This water is an asset of great possible value. It should be the habit of every acre-owner to compute it as a possible value, saved if turned where it will do good, lost if permitted to run away, doubly lost if it carries also soil values and does destructive work below. Let us repeat the story of its productive paths. A due portion of the rainfall should go through the soil to its bottom *to promote soil-formation* there; a due portion of this should go on into the underdrainage, *carrying away harmful matter;* a due portion should go again *up to the surface carrying solutions needed by the plants;* a due portion should obviously go into the plants to nourish them; while still another portion should run off the surface, carrying away a little of the leached soil matter. There are a multitude of important details in this complex of actions, but they must be passed by; the great features are clear and imperative.

Experimental studies have shown that, on the average within our domain, *crops can use to profit all the rainfall during the growing season, and much or all of that which can be carried over from the non-growing seasons.* This greatly simplifies the complex problem, for the highest crop-values will usually be secured when the soil is made to absorb as much of the rainfall and snowfall as practicable. There are, of course, many local exceptions. In securing this maximum absorption and internal soil-work, the run-off, and hence the surface wash, will be reduced to a minimum. It has already been seen that the wash of even this inevitable minimum is likely to be still too great to keep the proper slow pace with soil-generation, when the surface has much slope. Except on very level ground and on lodgment surfaces, there need be no solicitude about a sufficient removal of the soil surface. The practical problem then lies almost wholly in retaining and passing into the soil the maximum of the precipitation. Obviously this gives the minimum of wash to foul the streams, to spread over the bottom

lands, to choke the reservoirs, to waste the water-power, and to bar up the navigable rivers. *The highest solution of the problem for the tiller of the soil essentially solves the whole train of problems.*

How is this control to be effected? All the known and tried methods of preventing wash and turning the rainfall into the soil should be duly employed. It is obvious that all methods of culture and all crops that increase the granularity and porosity of the soil contribute to the end sought. Deep tilth to promote soil granulation and deep-rooting plants to form root-tubes are specific modes of great value. Artificial underdrainage by preventing water-logging and promoting granulation aids the end sought. Contour cultivation by arresting and distributing the surface wash may also assist. Alternate strips of protected and cultivated land, reservoirs for catching and distributing concentrated rainfall, and other devices, serve to limit the wash of the slopes and give the surface waters the right direction.

It is possible that some of the more radical and permanent remedies will be found by a closer study of nature's methods. Nature has been working at this complex problem of balance between soil formation, soil waste, surface slope, plant growth and stream development, for millions of years. Looking closely at her methods, we note that she uses a much larger variety of plants to cover and protect the soil than we do, and that these plants have a wider range of adaptation to the special situations where protection is needed. We may, therefore, inquire whether we should not follow this precedent farther by developing more kinds of profitable plants and by using the protective varieties more freely on slopes especially subject to wash. Forest trees are a resource of this kind and should be employed as fully as practicable, as will, no doubt, be urged with great cogency by those who discuss the problem of forestry. We also have many shrubs, vines and fruit trees, whose employment to the maximum in covering areas subject to wash is likewise urged, either alone or in conjunction with trees. We are forced to recognize, however, that for the greater part the berries and fruits which render these profitable are perishable and have limitations of preservation, transportation, market, etc. But if shrubs and vines could be evolved by modern selective methods, whose nut-meats or dry seeds should be available for food in place of the watery pulp, and which could be treated much as cereals are, and have similar wide year-round markets, there would be a larger choice of crops to grow in soils subject to wash, and we might secure soil-protection with less crop-limitation. There would then be less need to press the culture of the cereals so far as we do now, and they could be limited more largely to surfaces less subject to harmful soil-loss.

Another of nature's marked methods is the formation of plant-societies, or, from our point of view, combination-crops. No doubt

there is much deleterious crowding and repressive rivalry among the natural mixtures of plants, but at the same time there seem to be associations that are mutually beneficial. No doubt man secures a great temporary advantage by isolating chosen plants and freeing them from competition, but this is clearly at some permanent disadvantage which is partially corrected by rotation, fertilizing and tilth. Can not a greater advantage be secured by a larger use of the combination method? It is clear that legumes and cereals are helpful associates in rotation and in some combinations. May not the principle be pushed much farther by the modern processes of selection and culture, so that legumes and cereals may be made more intimate companions in culture; so that, indeed, such helpful associates may replace weeds as the constant and spontaneous companions of the crops we cultivate? While kept in such subordination as to be servants of the chosen crop, may they not still aid effectively in covering and protecting the soil and thus guard against undue surface loss. Certainly much can be done by such congenial plants, used as fall, winter and spring crops, to cover the soil when specially exposed to wastage.

These and similar devices may be used to reduce the bare surfaces so much developed by present modes of cultivation, and may make it possible to cover permanently by profitable protecting crops the slopes where surface wash is most menacing.

But a critical question remains to be answered: Can such modes of soil-management and crop-selection be made to give reasonable profits? Before we can hope that the millions who till the soils will join effectively in a radical scheme of soil-conservation, it must be made to appear that the scheme will give reasonable returns at every large stage of its progress; must pay, let us say, in the long run of a lifetime. We may fairly assume that intelligent people will be guided by the total returns of a lifetime in lieu of beguilement by the ultra-quick returns of forced and wasteful cropping in total neglect of later results. It may be assumed that he who tills a farm from his twentieth to his sixtieth year will find more satisfaction in the summed profits of forty crops of increasing value, enhanced by the higher value of his land at the end, *even though the margin above cost be no greater,* than in the sum of forty crops of decreasing values with a debased land at the end. Our practical problem is, therefore, to so improve processes, to so increase intelligent management, and to so exalt the point of view, that every large step in the processes proposed shall give satisfactory returns for the labor involved. How far this is practicable just now, I must leave to those whose technical knowledge in the practical art of tillage fits them to answer; but it is clear that if such protective measures are not profitable now, they must soon become so; for, if the loss of soil proceeds at the present rate and the number of inhabitants

continues to increase as now, the value of the residue of tillable land which will remain after a few centuries will so appreciate as to force extreme measures for its conservation. The pitiable struggles of certain oriental peoples to retain and cultivate the scant remnants of once ample soils is both an example and a warning. Our escape from such a dire struggle should spring from a clearer forevision, a deeper insight, greater technical skill and indefatigable industry.

Note.—Much valuable literature bearing on this and kindred subjects will be found in the numerous publications of the U. S. Department of Agriculture and the several State Agricultural Stations. Notable among these is the Farmers' Bulletin No. 20 on "Washed Soils," and a special contribution to "Soil Erosion" by W J McGee. The fundamental work on "Rocks, Weathering and Soils," by Dr. Geo. P. Merrill, of the National Museum, is also to be noted. Particularly valuable are the writings of Professor F. H. King on "Soils," "Soil Physics" and "Soil Management," and, especially for the south and west, the work on "Soils," by Professor E. W. Hilgard.

THE MISSISSIPPI RIVER PROBLEM

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THE project for a deep waterway from the Great Lakes to the Gulf has been dreamed about and discussed intermittently for half a century, but nothing definite ever came of it until a little over a year ago, when, from a conference held at St. Louis, there was born the permanent organization called the "Lakes to the Gulf Deep Waterways Association." That this concerted movement came at the psychological moment has been indicated by subsequent events. Last winter the Rivers and Harbors Congress in session at Washington supported the project. The president in his Memphis address heartily endorsed the enterprise; shortly afterward his annual message called attention to the need for river improvement and the question is now in the hands of congress with some definite action sure to come in the near future.

Within the last decade, this country has entered three fields of government activity, forest conservation, reclamation of arid and swamp lands and the building of the Isthmian Canal, the far-reaching results of which can scarcely be estimated at this time. The development of a ship channel through the Mississippi Valley, with feeding lines in the larger tributaries, would likewise be of such tremendous importance to the economic progress of the country that it must be ranked second to none in the list of great national policies.

A few simple statements of fact furnish striking evidence of the need for such a waterway. The drainage basin of the Mississippi system covers an area of approximately a million and a quarter square miles, or rather more than two fifths of the United States proper. This two fifths of the country is the real heart and soul of the nation's prosperity. With its development the United States has not only become independent of the rest of the world, but also has risen with tremendous strides to stand as the greatest producer of food-stuffs that the world ever has seen or ever will see. More than half the total population of the country to-day is found in the score of states bordering directly on the navigable portions of the Mississippi system. As the population increases the most rapid growth must be in these same states, until a century hence with hundreds of millions of people living between the slopes of the Alleghenies and the Rockies, there will exist in the Mississippi Valley the highest and most permanent type of civilization in the history of man. Three fourths of the world's cotton crop is raised

in the United States, and the heart of the cotton belt must for all time lie in Mississippi, Louisiana and Texas. Our corn crop is three times as great as for the rest of the world combined, and, though corn is widely grown both north and south, the chief corn belt naturally centers in the Upper Mississippi and Ohio Valleys. For example, five states, Illinois, Iowa, Kansas, Nebraska and Missouri, raise over half the total for the country, or, astounding as it may seem, nearly 40 per cent. of the entire world's crop. Wheat, cattle, hogs, vast quantities of oats, hay, potatoes, lumber, coal and other mineral products come mainly from the Mississippi Valley, each one in point of quantity leading all other nations of the world, and yet no one denies that the limit of productivity is far from being reached. Out of this list, cotton, meat products and bread-stuffs make up a large part of our foreign commerce, with half the world's mileage of railroads required to get the products to the seaports. As might be expected, by far the thickest railroad net is in the Mississippi Valley, yet the roads there have found their facilities increasingly inadequate to handle the produce of the region. "Shortage of cars" has become a familiar complaint in the wheat fields of the northwest. Corn and cotton in the states along the Mississippi have been kept out of the markets because of increased rates on rail shipments. On every side the farmers have raised the cry, "Better freight facilities," but the railroads have steadily failed to meet the demand. Conditions have gone from bad to worse until now the harassed producers see that their only salvation lies in the development of the routes so bountifully supplied by nature, with coordination of rail and water facilities to prevent disastrous opposition.

It is not a case of providing merely enough to meet present needs, for the growth of this vast interior storehouse still continues with gigantic strides. Irrigation, dry farming, swamp drainage, and the exploration of the whole world to give new crop species, are opening every year areas which have heretofore produced little or nothing, while crop improvement and intelligent soil management are adding millions of bushels to the yield of the older regions. Marked by developments unparalleled in the history of the world, there seems to be no limit to the enormous capacity to produce over areas measured in tens of thousands of square miles, areas whose crops alone determine panic or prosperity for the entire nation; areas wherein lie the sinews of the greatest and most stable world power in all history. Not England, nor Russia, nor China, not any other nation or continent of the world, can equal in all its territory the unbounded natural advantages of the Mississippi Basin. Yet with each added harvest the pinch of traffic congestion and heavy transportation charges are felt by an increasing proportion of the population, and as long as such conditions continue the full economic development of the region must be seriously hampered.

The logical solution of all the difficulties lies clearly enough in the utilization of the great arterial system of waterways afforded by the Mississippi and its tributaries. The time was when these rivers were the life currents of the region. In the days when river craft plied the Mississippi, Missouri and Ohio are found the conditions which gave birth to, and stimulated the growth of, St. Louis, Cincinnati, Louisville, Memphis, St. Joseph, Kansas City, Omaha and a host of other river cities of all sizes. To-day these cities are railroad centers, but by that very fact of having ready-made terminals the development of the water route takes on added value. Take, for example, St. Paul and Minneapolis, at the head of navigation on the Upper Mississippi, the greatest flour-milling centers in the world, shippers of hundreds of thousands of tons for both home and foreign markets and at the same time the logical railroad centers for a large section of our own northwest and Canada. Kansas City, almost in the geographical center of the country and undoubtedly destined to become one of the greatest inland cities of the continent, with St. Joseph, Omaha and Sioux City, all lie in the range of former navigation on the Missouri and stand as important shipping centers for the great corn, wheat and cattle trade of the country back of them. The vast quantities of products handled at these places are mainly bulky goods which do not suffer seriously from relatively slow transit, but which do need most urgently the means of getting to market at the lowest possible transportation charge. No better illustration of the advantage of shipment by water can be found than that afforded by the coal trade from Pittsburg to points on the Mississippi. Coal can be sent from Pittsburg to New Orleans by river, 2,000 miles, for about 75 cents a ton, while the rate by rail to Memphis, 807 miles, is over $3 per ton. On the basis of the charge per ton per mile, the latter rate is about ten times as heavy as the former, a fact which becomes strikingly significant when it is considered that a saving of a single mill per ton mile means $1,000 saved on every shipment of 1,000 tons going 1,000 miles. A similar saving on a comparatively small part of the annual cereal crop alone in those states bordering the Mississippi system would very soon reach a total surprisingly close to the entire cost of improving the navigation.

A waterway with a depth of fourteen feet from New Orleans to Chicago, with channels of less depth in the Ohio and Missouri, would almost unquestionably solve the problem of traffic congestion and high freight rates for a great area of the productive west. It would be a movement directly in line with the policies of various European nations, where far less valuable waterways in thickly settled districts have been utilized most profitably. It is an enterprise which the United States must inevitably undertake sooner or later as the density of population increases throughout the Mississippi Valley. Railroads,

thoroughly equipped, yet inadequate to meet the conditions of the present time, will be relatively less able to cope with the rapidly growing demands for transportation facilities in the future. Already in the more densely populated portions of the country waterways once abandoned are being rehabilitated. The country can not long afford to ignore the possibilities presented by the development of the greatest natural highway in the world—the Mississippi and its navigable tributaries. It can not be denied that the improvement of our greatest inland waterways will be followed by vastly more important industrial and commercial advantages than can ever result from the opening of the Panama Canal. These advantages would be not to the people of the Mississippi Valley alone, but to the people of every county and corner of the Union through their dependence on the products of this region.

The project, however, is not at all simple—it is an undertaking fraught with problems which, unless met rightly at the start, must inevitably defeat the entire purpose of improvement. Like all big rivers, the Mississippi and its tributaries have bad habits, the worst of which are devastating floods, followed by very low stages of water at other times; rapid changes in the course through sapping of the banks; and constant shifting of the channel, often over night, on account of the formation of sand bars. In these respects our rivers are not necessarily any worse than others, in fact, they are not so bad as many of the great rivers of the world, but the correction of these habits becomes an unavoidable and serious question when efficient improvement for navigation is undertaken. The question of river control and improvement is most intimately connected with forestry, farming, mining and other industries, since they in many cases largely determine the particular problems with which man must deal. In the Ohio the overwhelming spring floods and low water stages of summer are the chief difficulties, with slack water dams doing much to remedy the latter condition and make navigation possible at all times. The sand-bar evil in the Missouri is so great and so perplexing that it completely overshadows the question of flood control and sapping of banks, which are in themselves of no slight importance. Along the lower Mississippi from St. Louis to the Gulf all three problems urgently demand attention, since this portion of the river represents the trunk line of the entire deep waterways system; and it is just here that the physical conditions surrounding the river make correction or control the most difficult.

From St. Louis southward, the river course follows a broad alluvial plain, which gradually increases in width to about 100 miles near the Gulf. This broad river flat is composed of a soft, highly-productive soil, fine-grained and of indefinite depth, in which the river has developed such a tortuous course that while the air-line distance from Cairo

to the Gulf is about six hundred miles, the journey by water is twice as long. On every one of the many turns and bends throughout the whole twelve hundred miles the river is constantly undermining and wearing away the outer bank of the channel in just the same way as the outer rail of a curve on a railroad is worn rapidly and must soon be replaced. The fine-grained, loose character of the soil greatly facilitates the undermining action, especially during the irresistible rush of flood waters.

This habit of eating away its banks is perhaps the worst which can be charged against the lower Mississippi, and presents one of the most serious problems in the whole question of control. Needless to say the unceasing changing of the course is vitally important to the plantation owner, who sees his fertile land steadily vanishing, often at the rate of 300, 400 or more feet a year along his entire water front. It is still more important to the towns and shipping points located along the river. New Orleans is the only big city located directly on the river flat, and, fortunately for the city, it is at a place where the river's course is now comparatively straight. Other cities, like Memphis, Vicksburg and Natchez, are located on the high bluff where the river swings close against the eastern side of its valley. These latter towns have secured immunity from floods, but even simple changes in the channel would deprive them completely of their water fronts and strike fatal blows at their prosperity.

Even the present extent of the river traffic demands that there shall be more or less villages directly along the river and steamboat landings at various points, but every one of these places enjoys only a temporary existence. Since the river current hugs close along the outer side of every curve in its course, it follows that the deepest water, and hence the main channel, also lies near the outer bank. The natural result is that all steamboat landings and all important shipping points must be located on the outer banks of curves, as is found to be the case all along the river. The difficulty which lies therein is obvious enough, for with rapid undermining of the outer bank of all bends, the river is always tending to destroy the water front of every place so situated. The history of the landings below Cairo shows that practically every one of them has been driven back before the advancing river at the rate of 100 to 150 feet a year for the last quarter of a century.

That this condition is felt on a larger scale than by mere landings is shown by the case of Greenville, Mississippi. This city of nearly 8,000 people, the largest river port between Vicksburg and Memphis, is the flourishing commercial center for an important part of the lower valley, yet imminent ruin is even now staring it in the face. Greenville stands on the outer bank of a great curve in the river with three other curves up-stream from it. Narrow necks of land separate the

different curves, and these necks are rapidly disappearing as the banks cave in. Twenty-five years ago at the curve farthest up-stream from the city the neck was over 4,000 feet wide, five years ago it was less than half that width and was caving badly. The neck below the city is only half a mile wide and is also yielding rapidly to the attacks of the river. Greenville is confronted with these alternatives: If the neck below the city is cut through first by continued sapping, the city will be left high and dry, five miles from the river and its reason for existing will be gone. If, on the contrary, the neck above the city is the first to succumb, the resulting changes in the channel will cause most vigorous scouring of the bank exactly where Greenville stands and it will be speedily swept away. The levee now stands where the main street once ran and, despite every effort to stop it, the town has been forced to play leap frog over itself to keep away from the advancing river. Through the expenditure of a million dollars in protective devices the crisis has been delayed, yet the city is doomed eventually, and the money spent in its protection must be regarded as wasted.

St. Joseph, Missouri, with a population exceeding 100,000, and one of the most important centers of the west, faces a somewhat similar fate from the Missouri river. Opposite the city the stream swings around a great bend, St. Joseph being located on the bluff above the river bottoms. Some smaller villages on the flat have already been swallowed up in the stream, and, at its present rate, the current will soon cut its way through the narrow neck which lies a few miles west of the city, severing the Grand Island railroad, rendering the big steel bridges at St. Joseph practically useless, making new bridges over the new channel necessary, cutting off the intake of the water supply, and leaving the city without any outlet for its sewer system. Here, again, somewhat over a million dollars has been spent in river work above and below the city, but the banks have continued to cave, and St. Joseph is facing the prospect of being left higher and dryer than Greenville. From the standpoint of transportation by water, however, the loss of the river front at St. Joseph would not now be a serious calamity, since the Missouri route is at present rendered quite useless by the excessive formation of sand bars.

Both the federal government and the Chicago and Alton railroad have spent large sums in an attempt to control the Missouri at Glasgow. Kaskaskia, the one-time capital of Illinois, has been wiped out of existence by the changing current of the Mississippi, while the prospect of a cut-off at Cowpen Bend, above Natchez, indicates that the harbor of that city will be destroyel by the deposition of large quantities of sand along the entire water front. Striking as these individual cases may be in themselves, the question of this cutting away of the banks, accompanied by deposition of sand in other places, takes on far greater significance as soon as costly improvements are suggested. It is unde-

niable that what is happening along the river to-day is a true sample of what the river may be expected to do every day as long as the existing conditions prevail. A fourteen-foot channel presupposes important movements of goods from many points along the river. Large shipments can not be handled readily or economically without expensive modern terminal facilities along the river front, but the building of such terminal facilities can not be expected as long as they are threatened with the same fates as now confront Greenville, Natchez and St. Joseph.

The flood evil, the second great problem to be met in the control and improvement of the Mississippi system, has been fresh in the minds of every one since the disastrous spring of 1903, when the loss of property amounted to fifty or sixty million dollars. The flood problem applies not only to the main Mississippi itself, but perhaps even more vitally to its chief tributaries, the Missouri and Ohio, which must be regarded as the main feeders to any proposed improvement. The total loss from a few historic floods in these streams has been tremendous. In 1881 and 1882 the floods of the Ohio and lower Mississippi caused a loss of $15,000,000. In 1884 the Ohio Valley alone suffered to the extent of $10,000,000. An area twice the size of New Jersey was laid waste along the lower Mississippi in the spring of 1897 with losses again reckoned in tens of millions of dollars. The unprecedented ravages of the Missouri came in May and June of 1903, and finally this last year saw damage to an extent estimated at not less than $100,000,000 in the Ohio Valley. In the last quarter of a century, therefore, the plain money loss from a single half-dozen floods approaches a quarter of a billion dollars, while the sum total from all floods must be acknowledged to equal many times over the entire cost of the most effective and permanent means of protection.

The principal cause of the floods in the Mississippi is heavy or prolonged rains at certain seasons of the year, a primal cause, which lies beyond the power of man to control, but which has been greatly aided in its effects by wide spread deforestation about the head waters. Flood conditions vary widely in the different tributaries. The Missouri has the largest drainage basin of any of the tributaries, about 540,000 square miles, but the average rainfall over the region is small, unusually heavy and long-continued rains are less frequent, and, because of porous soils and excessive evaporation, only a small part of the rainfall passes off in surface drainage. As a result of these conditions, the Missouri supplies only about one seventh the total discharge of the Mississippi, and is, on the whole, as regards floods, the least important of the large tributaries. The upper Mississippi, with a drainage area only a third as large as that of the Missouri, turns in about one fifth the total volume of the main stream, while the Ohio, draining approximately 200,000 square miles, sends down a third of all the water discharged

by the Mississippi. These three rivers, therefore, yield over 60 per cent. of the gross volume, the remainder being divided between the White, Arkansas, St. Francis, Yazoo and Red rivers, which join the main stream too near the mouth to be important factors in the production of severe floods.

The Ohio is, on the whole, much the worst flood offender, partly because of its normally greater volume, and partly because of the conditions existing in the region it drains. The major portion of the areas drained by the Missouri and the upper Mississippi are distinctly less rugged than the Ohio basin, and over both areas the heaviest rainfall, coming in May and June, arrives at a season when the soil can take a large percentage of it. The largest tributaries of the Ohio, on the contrary, in etching their valleys in the surface of the Allegheny plateau, have produced the steepest and most rugged parts of the whole Appalachian region. Here the heaviest rainfall comes in January, February and March. Add to these factors the frequent complications of melting snow and frozen ground, which sheds water like a house roof, a district largely deforested, and the enormous destruction by sudden rising of the Ohio is explained. It is truly fortunate that by the provisions of nature the three rivers, the Ohio, the Mississippi and the Missouri, have never been known, and probably never will be known, to be in extreme flood at the same time. Such an unhappy coincidence of high stages, if it came about, would quite certainly mean total obliteration for everything in the lower valley.

The flood evil is in a large way the underlying cause of most of the trouble in the Mississippi. At time of flood, the erosive power of the river is increased a hundredfold, caving of the banks is often excessive, levees situated rods from the channel before the flood and apparently safe are undermined, and the narrowing of necks between bends is greatly accelerated or quickly accomplished. Much of the damage from floods must be laid to the cavings of banks by which landings are destroyed and whole plantations are soon swept away, while through breaks in the undermined levees the raging waters sweep over the surrounding country. This spread of the flood is fostered by the fact that the river channel lies above the surrounding bottom lands. To the naked eye the region appears absolutely level, but from the river the broad plain slopes away at a rate varying from four to thirteen feet per mile. Once outside its channel, therefore, the water finds a natural course down hill into every part of the back country, carrying destruction wherever it goes. Unfortunately, this character of the river can not be altered; on the contrary, the more the river is confined between artificial levees and restricted in the area over which it is free to spread, the greater will be the devastation whenever a flood does occcur, so that with the extension of the levee system the occurrence of floods becomes an increasingly serious problem. The recognition of this fact

can not be urged too strongly, for until the flood waters are under absolute control, the construction of a deep channel, no matter whether it be in the river itself or in the form of a canal along the stream, must be done in the face of constant danger of having the entire system crippled and large portions destroyed whenever overflow takes place.

Again, when the river is in flood, as it is to a certain degree every year, it is carrying along the greatest amount of sediment, much of which represents the most fertile part of the soil. The total amount so carried is almost beyond conception, but to carry it by freight train would require 500 trains for every working-day in the year, each train consisting of fifty cars with a capacity of fifty tons. Besides this tremendous quantity poured out into the Gulf every year, other incalculable masses are deposited as bars all along the course, and as the water falls to its normal level these bars are a constant menace to every form of navigation. The presence of these obstructions and their rapid shifting from day to day has always been one of the most serious handicaps to river transportation. In fact, the abandonment of navigation on the Missouri may be laid entirely to the utter inability to cope with the shifting sands. Deforestation, cultivation of the land especially, and mining operations, are vitally important in the question of soil washing, surface erosion and the amount of sediment in the streams.

The project for a deep waterway for commercial purposes, therefore, is confronted with these serious problems which must be solved before the government can afford to spend one or two hundred million dollars in river improvement. Some system of control must be devised to insure to water fronts and terminal facilities a reasonable degree of permanency through protection against erosion of the banks. There must be some way of checking disastrous floods which would in a single season, and perhaps year after year, destroy improvements costing millions of dollars—as the experience of some of the eastern canalized rivers indicates. The prevention of low-water stages is no less important, since marked variations in the water level make it difficult to establish the necessary terminal facilities. Finally, the formation of sand bars must be stopped, otherwise it means stupendous, unending and probably ineffective, dredging operations in an attempt to keep the channel open.

If the Missouri could be removed from the list of tributaries by giving it a separate mouth, the sand-bar problem would no longer exist, since that stream contributes over 60 per cent. of the total brought into the Mississippi. Reducing the load by 60 per cent. would certainly mean that the Mississippi could then keep its own channel clear. But the idea of providing a separate course for the Missouri from St. Louis to the Gulf is too daring even to be suggested. Moreover, it would

remove from the immediate benefit of the deep waterways project those important communities which hope for renewed navigation on the Missouri.

If the entire lower Mississippi were given a new course free from sharp bends, as could be done readily by cutting through the successive necks, the sapping and caving of banks would cease and the distance from St. Louis to New Orleans would be lessened nearly by half. That this plan is entirely feasible is amply demonstrated by the success of the Germans in correcting and straightening the Rhine. The Rhine, if possible, presented a more difficult problem than does the Mississippi, but the German engineers recognized the fact that where sharp bends exist it is impossible to prevent entirely undermining and caving of the banks. Acting on this principle, it was decided to give the river a practically new course, less winding than the former, and in which future control is insured. Unfortunately, this procedure applied to the Mississippi would not be an adequate remedy for the floods, nor would it effectively prevent the formation of sand bars. It is unquestioned, however, that the flood stages would run off more rapidly and a greater amount of sand would be scoured from the channel, since in a shortened course the river would have a steeper descent and consequently a more rapid flow with increased carrying power. The corrected course undeniably has much to recommend it, aside from the mere facts of feasibility and a shorter route.

If the high-water stages of floods could be prevented and the flow of the river controlled, the practical solution of the question would be at hand, for the major part of the sediment is washed into the streams incident to the flood time, and the excessive flood volume causes most of the caving of banks. For a good many years the federal government has been at work on the Mississippi, building levees to control or prevent floods, placing revetments along the banks to check the caving action, and operating powerful sand pumps to remove the shifting bars. It is estimated that in the last forty years the government has spent all of $225,000,000 on the Mississippi and its more important tributaries, not a single dollar of which has gone toward permanent improvement, except in the case of the jetties at the mouth, the slack water dams on the Ohio and the removal of rock ledges at a few points. Fifty million dollars of the total amount has gone into the construction of some 1,400 miles of levees and revetments along the lower course, but before the national government undertook the task of control, the states of Mississippi, Louisiana and Arkansas had already spent not less than $40,000,000 toward the same end. Enough similar work has been done at one time or another by private individuals, so that, first and last, the levee-revetment system to date represents an outlay of fully $100,000,000. Yet not one cent has been devoted to the control of the excessive floods which come almost every

year in some of the tributaries, simply because the levee method can not be applied there. It must be admitted that the levee system affords fairly efficient protection from ordinary floods, in so far as damage from overflow in the lower valley is concerned, but its desirability is seriously impaired by the fact that the levees must be constantly replaced. Just as long as the river is allowed to swing against its banks the soft alluvial soil will continue to cave in; levees originally built back from the channel are eventually undermined, rendered useless, and then in cases of high water stages, unless a second line of levees exists, the entire region is open to devastation. Until the sapping action of the river is under control there can be no such thing as a system of levees built once for all. Even the most optimistic advocates of this plan do not claim more than twenty to thirty years for the life of any levee.

It is undeniable that the army engineers in charge of the work have accomplished much in saving large areas from annual inundation, but they have not to any extent permanently improved the river as a highway of commerce. Furthermore, they have signally failed in the attempts to stop erosion of the banks, for past experience shows that no style of revetment yet devised will offer more than partial or brief protection from that action. In fifteen years some landings have been forced back more than a mile, and at important points where careful revetting has been done the retreat is said to have exceeded 1,000 feet. The levee-revetment system as now practised may be the simplest way of protecting agricultural interests on the river flats, but it is certainly not the most economical in the end, nor does it in any way afford even a temporary solution of the great problems confronting navigation and river commerce. The heavy expense of maintenance must go on without end until the sum total of expenditure will aggregate vastly more than the cost of the proper, permanent remedy. The most serious of all the shortcomings charged against present methods, however, is that they do not strike at the root of the evils. The place to control floods is where they originate, in the tributaries, and thus protect both tributary and main valleys; as well try to fight fires by blowing away the smoke as to control the floods by levees along the lower course. To improve the river to the extent of a fourteen-foot channel to St. Louis would be a foolish waste of money as long as the levee-revetment system is the chief method of control.

Various other methods of control have been suggested from time to time, but most of them do not appear feasible or to offer the desired results. The rearrangement of tributaries, either by diversion or by addition, has been advocated, since the addition of tributaries to the Po very materially lessened the flood evil, the increased volume and velocity having caused a marked deepening and widening of the channel. In the Mississippi case, however, there are no important streams which

could be added, and the only possible source of increased volume is by giving the Great Lakes an artificial outlet by way of the Illinois River. A certain amount of diversion or rearrangement of tributaries would be possible, though not very practicable, as in getting rid of the load of sediment from the Missouri, or in turning the Tennessee through the Big Hatchie River to reduce the Ohio floods. But in all of these radical schemes the possible benefits to be derived are far outweighed by the inevitable difficulties and disadvantages. It is unquestioned that the tributary system must remain as it is now.

The construction of artificial outlet channels to take off the excess volumes which produce floods has been suggested many times, and it seems likely that if constructed in sufficient numbers they would prove effective. There would, however, always be great difficulty in keeping the outlets sufficiently free from sand so that their usefulness should remain unimpaired. A second and more serious objection to the outlet scheme is that in the lower valley, where the flood control is most difficult and the flood damage most wide-spread, the outlets would have to be provided by turning the water over the low-lying bottom lands. Outlet reservoirs could not be maintained because of the sand and mud with which they would be speedily filled. Under such conditions, therefore, the outlet plan clearly defeats one of the chief objects of flood control—the protection of rich plantations covering thousands of square miles on the river bottoms.

The solution by building a series of reservoirs in the head-waters of the chief tributaries appears to be the cheapest and most certain remedy for all these difficulties. By the construction of reservoirs the excess of water which produces flood stages could be impounded and held up with these important results: excessive and destructive high-water stages could not occur, while, on the other hand, by regulating the discharge from the reservoirs, a more even flow of water could be maintained at all times, eliminating to a large degree the losses from diminished water supply, reduced power and fouling of streams incident to the low stages of late summer and early autumn. As soon as the irresistible rush of flood waters is stopped the sapping and caving of banks will be reduced to a minimum, with the efficiency of revetments increased many fold; finally, cutting down the flood volumes means a great diminution of the amount of sediment carried, and a marked alleviation of the sand-bar evil. The reservoirs would, moreover, eliminate floods from the whole system, not merely from the lower course. The prevention of the annual flood damage in the Ohio would in itself be worth the entire cost of the reservoirs, yet until the work of control is carried to the headwaters no relief can be secured for that populous valley.

The solution by head-water reservoirs, of all proposed plans, has probably provoked the most discussion—on the one side, those who

regard it as impossible, or, at least, highly impracticable; on the other side, those who consider that it is not only feasible but at once the only proper remedy. It is admitted by every one that the topography of the country about the head-waters of the Mississippi system is especially well adapted to the construction of retention dams and reservoirs. The arguments advanced against this plan, though admitting this condition of favorable topography, maintain that sufficiently large reservoirs could not be constructed and made safe or, in other words, they would, through danger of bursting, be a constant menace to the whole valley below the retaining dam. Again it is argued that if this plan were adopted, the building of reservoirs would have to be done on an enormous scale, since destructive floods often result from local conditions, such as a swollen tributary superimposed on an already swollen river. This necessity for a widely extended system of reservoirs, it is further claimed, would involve such tremendous expense as to make the adoption of the plan impossible. Most of these supposed objections are still based on a report made to congress nearly fifty years ago, and, whether good or bad arguments then, there is no question that they do not apply now.

It is flying in the face of cold facts to contend any longer that reservoirs to retain the flood waters can not be built, or not without danger to the entire valley below. The Ohio floods of 1907, the most disastrous for more than two decades, were due to an excess of water estimated at 23,000,000,000 cubic feet. To hold every drop of that excess discharge would have required a reservoir only a little more than half as big as the Pathfinder irrigation storage reservoir on the North Platte River in Wyoming, or one third of the size of the reservoir in the Salt River project in Arizona. The Engle dam on the Rio Grande, a hundred miles north of El Paso, Texas, will impound about 120,000,000,000 cubic feet of water, equal to one sixtieth of the total annual discharge of the entire Mississippi system, or more than five times the quantity of water causing the most destructive Ohio flood in a score of years. These reservoirs are being built by the government at a cost of about $4,000,000 for the Pathfinder dam, $5,300,000 for the Salt River project and $7,200,000 for the Rio Grande reservoir. Furthermore, it is expressly stated by the Reclamation Service that the Wyoming reservoir and the Engle dam will absolutely control the worst floods which the North Platte and the Rio Grande have ever known, the latter of these streams having been a notorious offender in flood damage. The mere fact of being able to retain the flood waters in impounding reservoirs can no longer be denied, nor can the claim of danger from breaking dams be now advanced as a valid argument against this system. This government is most assuredly not spending millions in reclamation projects and encouraging thousands of people to take up

irrigated lands if there is any remote likelihood of having homes, property and lives wiped out in floods from bursting reservoirs.

Granting, then, that the reservoirs are feasible, there still remains the question of expense in constructing the number necessary to place one or more in each of the most important tributaries. Estimate the expense most generously, letting each one cost a third more than the Engle dam above El Paso, and the total figure then is less than what has already been spent on the Mississippi system. But there is another important factor to be considered—the tremendous possibilities which lie in the development of water power from each reservoir. The question of future motive power for industrial purposes, as the coal supply decreases, is a problem which must soon be met in this country, and probably will be solved by the use of water power either directly or through electricity. In fact, even now, water rights are being rapidly acquired and developed on every hand, as the advance guard of the change that is to come. A sample of what a storage reservoir will do can be seen in the case of the comparatively small irrigation project at Minidoka, Idaho, which will develop about 30,000 horse power per year. Renting this power at the very low figure of $10 per horse power per year would pay for the entire Minidoka project, reservoir, irrigation-canals, gates and all, in six years. The amount of power generated by the Mississippi system is variously estimated high and low, with 60,000,000 horse power per year as an intermediate figure. Much of this amount is not directly available, but granting on a conservative basis that a series of impounding reservoirs would develop immediately 2 per cent. of that amount, there would be 1,200,000 horse power to be turned into electricity and distributed to factories. A purely nominal rental would be ample enough to repay in two or three decades the entire original expense of the system, besides a good income on the investment. The reservoir system, however, must be intimately associated with forest conservation as a vital factor in regulating surface drainage and in checking the amount of soil erosion which supplies sediment to the river.

The proper building of reservoirs in the headwaters, therefore, offers what no other plan can possibly offer: it promises effective regulation of river stages and water supply for all time to come, removing entirely the liability of destructive floods, checking the erosion of banks and preventing much of the formation and shifting of sand bars and the pollution of water which the presence of sediment means. At the same time it provides a way of actually paying for itself in short order, aside from all idea of the savings to shippers and river interests in general which would be in excess of the cost. The importance of this latter consideration is emphasized best by a brief comparison with the system now being followed. The levee-revetment system, as mapped out, calls for an expenditure of $60,000,000 for its completion. From

the engineers themselves comes the statement that the average life of a levee is not over twenty years, which means this and no more: in two-score years, at the most liberal estimate, the present system, completed, will have disappeared entirely and a new series of levees constructed at the cost of another $60,000,000 will have taken its place, with conditions then no better than they are now. Considered solely on their own merits from the standpoint of control afforded, the present system has nothing, and the reservoir plan has everything, to recommend it.

In order to bring the river route to its highest possible degree of efficiency, it would be necessary to combine the reservoir system with a straightened course for the lower river, by which combination every evil would be removed and absolute control for all time would be insured. The reservoirs would make it possible to regulate the flow of the streams, preventing both floods and very low water, and at the same time, through developed horse power, pay for the improvements. The corrected or straightened course would shorten the route and effectively put an end to caving of the banks with all the difficulties arising from it at present. Together the reservoirs, with the necessary forest conservation and corrected course, would remove the sand bar problem—the one greatly lessening the actual amount of sand carried into the river, the other giving the current increased power to sweep its own channel clean.

It is undeniable that this plan calls for a large expenditure for its completion, but in the long run so does the levee-revetment system, without anything tangible to show for the outlay in the end. The whole question narrows itself down to a single issue: whether it is not better policy to do the right thing at the start, even if it require great initial outlay, rather than follow a plan which means the reconstruction of part of the so-called improvements every decade for centuries, with the region concerned always chafing under the handicap of a mediocre, inadequate waterway and suffering heavy annual losses from uncontrollable floods. The waste of money on levees and revetments ought to cease once for all. Let the federal government authorize the completion of the entire reservoir system with a straightened course for the lower river, and loose the bonds which every year are drawn tighter over this heart of our nation.

THE HIGH SCHOOL COURSE[1]

By President DAVID STARR JORDAN
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IT has been lately said by an honored teacher that the weakest part in our educational system is the high school. It has less unity in theory and less definiteness in practise than any other, and those who have charge of its administration are less sure that they are doing the right thing, than is the case with other types of schools. "As a forcing house between grammar school and college," says a recent writer, "the high school hasn't time to do anything very well." Hence it may be well to try to do fewer things, thus saving time to do some things better.

If we were to start at the beginning of education we should change a good many things. Especially should we distinguish between the college and the university in making the former the stepping-stone to the latter. But accepting our colleges and universities as they are, at the same time discarding the results of tradition and of half-hearted experiment, what should the high school do? By high school we mean the instruction in the public school for four years of school life from the age of 13 or 14 to that of 17 or 18, resting on the primary and grammar school on the one hand and presumably leading to the college on the other—in most cases the last of the years in which a student lives at home and goes to school.

The high school as thus defined has these duties clearly indicated: to give a rounded development of physical and mental powers, so that no line of talent shall perish by default; it should indicate and emphasize that form of ability which will count for most in the conduct of life and it should do its foundation work with such thoroughness that the higher education may be built upon it with the certainty that the attainments shall be solid so far as they go. This is all that the colleges and universities have the right to ask, and for them to specify certain classes of subjects regardless of the real interest of the secondary schools and their pupils is a species of impertinence which only tradition justifies. To demand thoroughness of secondary instruction and to enforce this demand in any practicable way is the duty of the college, but the question of what the high schools shall teach is a question for these schools to decide for themselves. In general, the high-school

[1] Address before the California State Teachers' Association, Santa Cruz, 1907.

graduate who has a training worth while in the conduct of life is also well fitted to enter college for further training. In general, too, the high school must consider its individual students. A well-rounded training for one is a very lop-sided discipline for another, and the development of special interests must not be overlooked. For these reasons a considerable range of choice is necessary in a good high school. This does not, however, imply an elective system such as the colleges have found necessary. In an ideal high school system the election should be mainly in the hands of the teachers. But at the same time the wise teacher makes sure that the student maintains a continuous interest in something. The lack of such sustained interest is the main reason why most of the boys drop out of the high school to get where they will be doing something dealing with things, not words.

It is clear that even yet with all the advances or encroachments the sciences have made, the study of words still fills too large a part in our secondary schools. The traditional college education was a training in words. It is easier and cheaper to teach language than anything else. The average child learns words by rote, while other subjects demand a more complex method, and the tendency is to fill the child with words regardless of the dyspepsia and disgust the abnormal diet may produce.

In my judgment, with the average student and especially the average young man, some study of natural science ought to go with every year in the school. The child is surrounded by a world of actualities, each producing a definite effect on his senses. In an out-of-door world, he recognizes that external things are real. He knows that the sun rises in the east, and he soon learns the various phases of woodcraft and fieldcraft—how to comport himself in the presence of realities. The constancy in these relations gives to him a kind of moral training, and the knowledge he obtains he wins at first hand. It is acquired in terms of his own experience and in such terms all real and helpful knowledge must always be stated.

In our cities we can not replace the training of the farm, the knowledge of the woods and hills, but we can continue to give in some degree, the essential part of it—contact with realities and extension of knowledge in terms of experience. This is through real contact with animals, plants, rocks, chemical compounds and physical instruments, and a well-conducted scientific laboratory has the same value as out-of-doors experience, with the great addition that it can be made systematic and therefore effective for power. The value of genuine nature study, study of science in out-of-door laboratories is of the very highest order. Not so the imitation nature-study, the study of sentimentalisms about nature, of nature words smothered in painted adjectives, now popular in some quarters. Of still less value are the nature books written as pot-

boilers by men who would turn out dime novels or problem plays just as cheerfully if the literary current set in that direction. The student of realities in nature and the "nature-fakir" are not on speaking terms with each other.

Once the student cuts entirely loose from real objects, and spends his days among diacritical marks, irregular conjugations and distinctions without difference, his orientation is lost. He loses the distinction between what is inherently true and what is true by agreement among men. He does not go far enough to touch bottom again in the real science of philology. And the average American boy quits the high school in disgust because he can not interpret its work in terms of life—he can not see how its work is related to the world of things as they are.

As to the relative value of the sciences, that is a minor question. Those sciences are best which give largest play for observation and judgment. Those sciences are best which can be taught best, with most accuracy and most enthusiasm. In general, it is better to teach one science well than two imperfectly, and the reason for teaching any science is its helpfulness to the mind, not the fact that there may be money in knowing it. But to have any value at all the science we teach must deal with realities, not book-science. "If you study nature in books, when you go out of doors you can not find her."

And this, too, is a reason why manual training of some sort ought to form some part of every well-balanced school course. Training of the hand is really training of the brain. This is a motor world we live in—a world in which men do things. We of America are preeminently a motor people. We do things. What can I do with it is the first interest of every child. And to learn to do things with the hand is of greater value as mental training than the disentanglement of phrases, or the memorizing of lists of verbal irregularities. The development of manual training of some sort for all boys and girls will represent the greatest immediate forward step in secondary education. But the purpose of this training must be intellectual, not to teach a trade, and only secondarily to fit for the engineering courses of the universities.

As the third of the three most important duties of the high school, I would place the mastery of English. The student ought to learn how to write good English—clear, accurate and straightforward. He should read enough good English to know it when it is written. He should study poetry enough to know what it is about, and if he is to do any memorizing, there is nothing that enriches the mind so much as the memory of good verse. I do not know how good English can be taught. Most of the students who use it seem to have grown up in it rather than to have learned it in the schools. But it is the most

important tool of every man who possesses it. It is wanted in every profession in every walk of life. The high-school course of every man who acquires it must be judged successful and no pains should be spared to emhpasize its importance. How to give this power is another question. Probably the real teacher of English, like the poet—which indeed he must be—is born, not made.

The rest of the high-school course has a minor claim on our attention. Algebra and geometry have a high practical as well as definite intellectual value. These constitute, moreover, the only door to the profession of engineering. History may be learned in the high school, but its significance is mostly seen later. The practical demands of intelligent citizenship seem to call for modern history, elementary economics and civil government as high-school subjects. Besides, those who do not go to college will read no history they do not begin in the high school. The languages, ancient and modern, have a high value to those who can master and use them, for every new language opens to a man a new world and the influences of a new civilization. Most high-school students get very little from any of them, and the one intellectually most important—the Greek—is practically excluded from our secondary schools as being of least practical value. Without in the least underrating the value of Latin to "roman-minded men," who make a manly use of it, there is no doubt that the average American high school boy gets less out of Latin than out of any other subject in the curriculum. We may regret this, but we must face it as a fact. For the rest, drawing ought to have a place in the course if only for its value as an aid to observation. "A pencil is one of the best of eyes," as Agassiz used to say, and drawing is one of the means of expressing observation in terms of action.

In brief, the American high school ought to limit the range of its activities so as not to do too much at the expense of thoroughness. It ought to broaden its range so as to give to each boy or girl what is individually best, and it ought to keep in touch throughout with realities, with the power of doing things, and it ought to cherish as its choicest art, the cultivation of the power of clear, accurate and original expression in the greatest of all languages, which is our own.

COUNT RUMFORD

By JOHN CANDEE DEAN
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THE annals of history do not record many geniuses who, with so little effort, and in so short a period of time, attained the high position occupied by Benjamin Thompson. In England he became colonel in the army, under secretary of state, knight, fellow of the Royal Society, founder of the Royal Institution. In Bavaria, minister of war, major general, count of the Holy Roman Empire; counselor of state, chief of state. In France, member of the Institute of France and lecturer at the Academy of Sciences.

Thompson was born on a farm at Woburn, Mass., in 1753. His father died when he was an infant, and his mother, having but a narrow income, took him from school before he was thirteen years of age and apprenticed him to a merchant at Salem. His thirst for knowledge was even then insatiable, and he found it impossible to apply himself to anything except his favorite subjects of study.

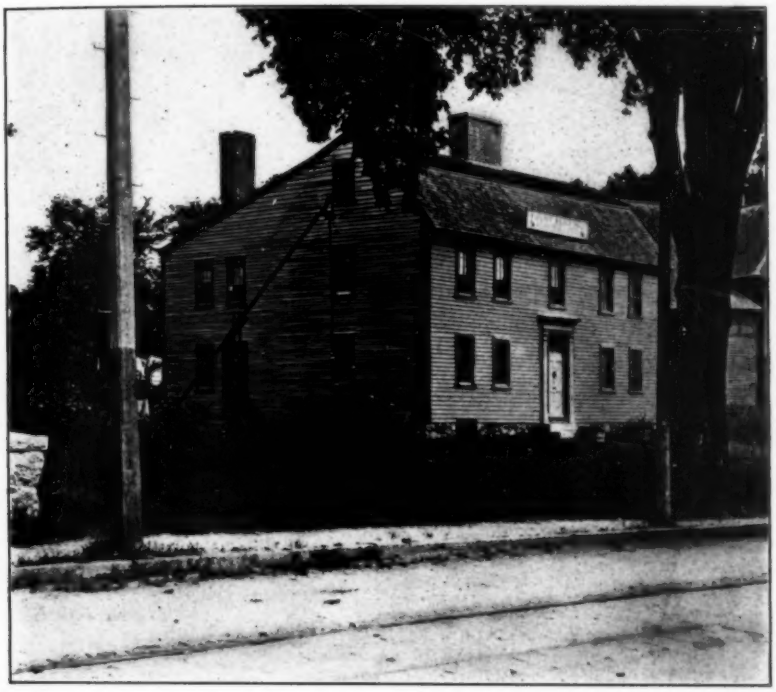
His scientific work began at Salem, where his zeal for experimenting nearly ended his career. Having undertaken to prepare some fireworks for celebrating the repeal of the Stamp Act, the ingredients of a mortar exploded, burning his face so seriously that it was thought that his eyesight had been destroyed, but in a few weeks he recovered.

The impending American revolution put a stop to his master's trade, and he thereupon left Salem for Boston where he continued his studies, to which he added medicine, anatomy, French fencing and other accomplishments, meantime supplying himself with necessary funds by teaching school in adjoining New England towns. He allowed himself but seven hours' sleep, the remainder of the twenty-four hours being devoted systematically to reading, study, experiments and exercise.

The American revolutionary period was prolific of great men. Washington, Franklin, Jefferson and Thompson were produced from a population of less than three millions. It is doubtful whether the vast population of the western hemisphere has since produced one man to rank with these four gifted men.

When nineteen years of age Thompson moved to Concord, New Hampshire, where he continued his profession of teaching. Here he met Mrs. Rolf, a young, attractive and wealthy widow to whom he was soon married. Among the prominent people whose esteem he won

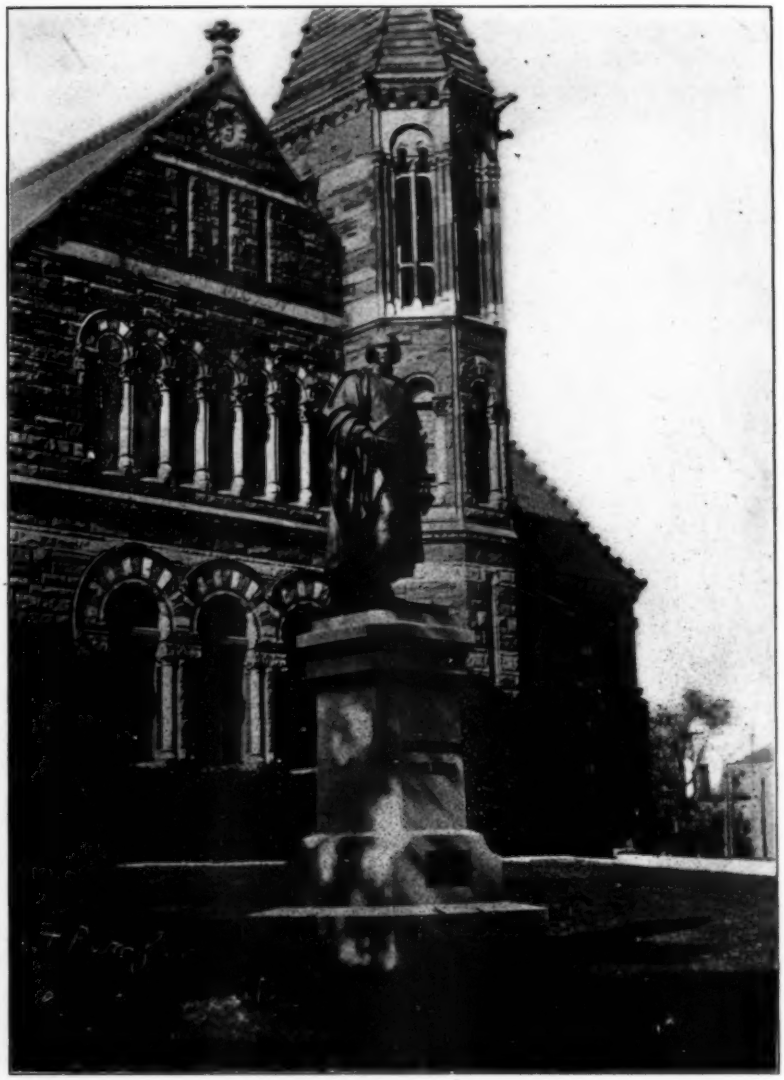
was Governor Wentworth, who made him Major of the Second Provincial Regiment. This appointment aroused hostile criticism from Thompson's fellow officers, who could not repress their indignation on learning that a young man, not yet of age and without military knowledge, had been raised above veterans whose long service justly entitled them to advancement. It will be shown presently that this incident prevented Thompson from engaging in the revolutionary struggle and led him to foreign lands where his genius had a wider field for



BIRTHPLACE AT WOBURN, MASS.

development, and where he soon became closely associated with the most learned and accomplished men of Europe.

In 1774 he left Concord with his wife and infant child and returned to Woburn. Charges were circulated that he was unfriendly to the cause of American liberty, and soon after the battle of Lexington he was arrested, and confined at Woburn. His case was heard by the Town Committee of Correspondence, by whom he was released. The principal evidence presented against him was that he had employed on his farm two British deserters, who, wishing to return to the British army, applied to their employer to secure immunity from punishment. Thompson complied by giving them a letter to General Gage, in which he asked that his efforts in their behalf be not disclosed.



RUMFORD'S STATUE AT WOBURN.

Major Thompson sought to redeem his reputation by entering the continental army. He applied to General Washington, then at Cambridge, for a position in the artillery, but his enemies had preceded him and his services were declined.

Deeming it imprudent to longer remain at home, he left Woburn in October, 1775, boarded a British vessel at Newport, by which he was conveyed to Boston, where he remained until the British evacuation. He then sailed for England bearing despatches to Lord Germaine, announcing the fall of Boston. Altogether Major Thompson was a bearer of bad news, friendless, poor and but twenty-three years of age, yet he so impressed Lord George Germaine with his intelligence, graceful manners and knowledge of American affairs that he was at once taken into his employ. In less than three years from the time of his arrival in London, he was advanced to the position of under secretary of state.

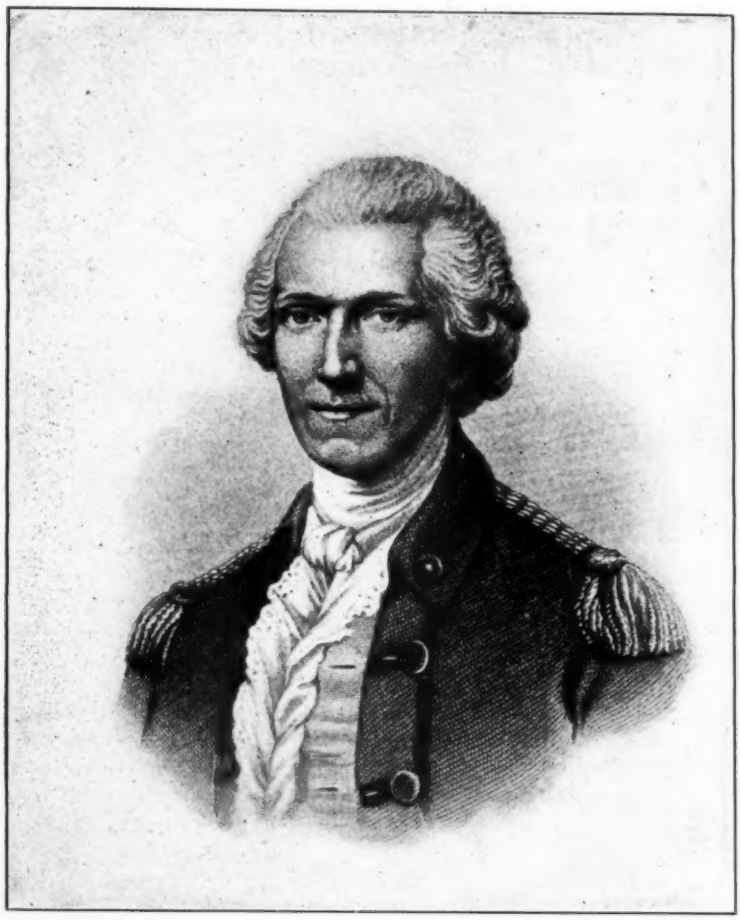
Judge Curwen, a tory refugee from Salem, Mass., then residing in London, wrote in his journal:

> This young man, when a shop lad to my next door neighbor, ever appeared active, good natured and sensible; by a strange occurrence of events he is now the Under Secretary of State to Lord George Germaine. His income arising from this source is, I am told, near 7000 Pounds a year. He is besides a member of the Royal Society.

Thompson made a series of experiments to test the cohesive attraction of different liquids, the results of which he communicated to Sir Joseph Banks, as a means of introduction to that eminent naturalist, then president of the Royal Society. This self-introduction was so successful that he was placed in Sir Joseph's intimate circle of friends, and he soon became one of the most active members of the Royal Society.

His activities were prodigious. He made a careful study of military details; advised and procured the adoption of bayonets for the fuses of the Horse Guards for fighting on foot; extended his experiments with gunpowder; determined the proper position for the vent in fire arms; measured the velocity of bullets and cannon shot; determined the rapidity of combustion and pressure of gunpowder; published a pamphlet on naval architecture; made a series of experiments in firing broadsides with the frigates of the Channel Fleet, commanded by his worthy friend Sir Charles Hardy; cultivated the acquaintance of men of station and distinction everywhere; and in addition to all of the above—as under secretary of state—he had the oversight of the details of recruiting, equipping, transporting and victualing, the British forces.

When the official news of the surrender of the British forces at Yorktown reached London, Lord George Germaine and his under secretary were obliged to resign, because of the fall of the administration of



PORTRAIT AT THIRTY YEARS OF AGE.

Lord North. The friendship of Viscount Sackville secured for Thompson a commission of lieutenant colonel in the British army, and he sailed for New York to command a regiment of cavalry, but contrary winds compelled the ship to enter the harbor of Charleston, S. C., where he remained for several weeks, finally reaching New York in January, 1782. The war soon being at an end, he left for England in the following April, after seeing but little actual service in America.

Having been advanced to the full rank of colonel, and there being no activity in the British army, he determined to add to his fame by volunteering in the service of Austria against the Turks. On receiving permission from the King to visit the continent, he left England, still holding his commission and drawing the half pay of a colonel.

He was now thirty years of age, strikingly handsome, with bright blue eyes, dark auburn hair, nearly six feet in height, athletic, a grace-

ful horseman, a skillful swordsman, spoke French and German, thus possessing all the accomplishments of a veritable Admirable Crichton.

When crossing the Channel his fellow voyager was the historian Gibbon, who, in writing to Lord Sheffield, described his companion as "Secretary, Colonel, Admiral and Philosopher Thompson." On arriving at Strasburg he found a military review in progress, commanded by Prince Maximilian of Bavaria, then field-marshal in the service of France. Thompson had taken several blooded horses with him from England, and he appeared at the parade mounted on one of his English thoroughbreds in the full uniform of a colonel in the dragoons. He at once attracted the attention of the prince, who invited him to dine, and was so delighted with his company that he asked him to pass through Munich, giving him a letter to his uncle, the elector of Bavaria.

Although he spent but five days at Munich, he so captivated the elector that he was earnestly invited to enter his service; but still desiring to engage in military service, he continued his journey to Austria. At Vienna he was presented at court, mingled with the first society, and received the most flattering attention. While still at Vienna he received another pressing invitation from the elector of Bavaria to return to Munich.

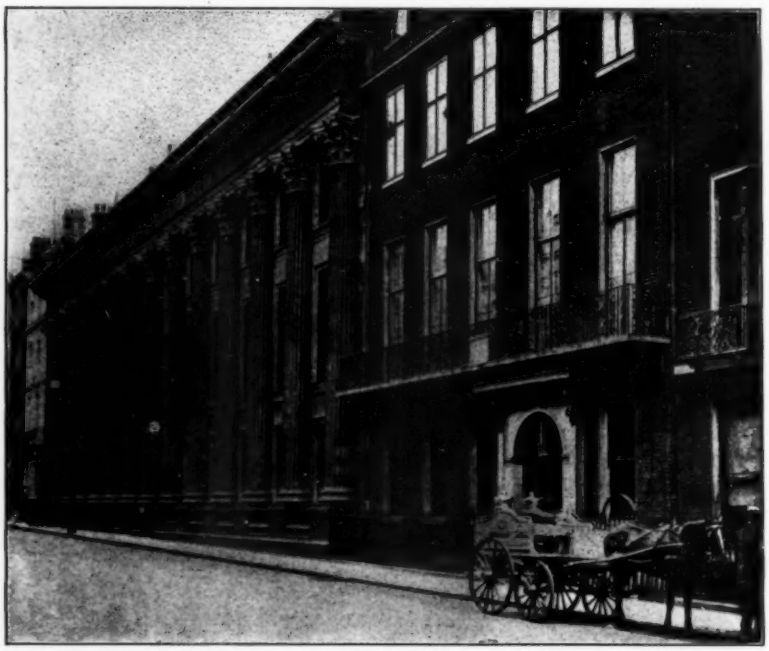
Finding that the war with the Turks was at an end, and deciding to accept the elector's offer, he returned to England for the purpose of obtaining the king's permission to serve the elector. In granting his request, George III. conferred on him the title of knighthood.

This soldier of good fortune now entered Bavaria as Sir Benjamin Thompson, soon to be privy counselor of state to the elector. Only twelve years had elapsed since he had taught school in small New England towns, and only fifteen years since he stood in the streets of Boston selling fire wood that he had cut with his own hands and hauled to town. On his arrival in Munich, his energy and enterprise were allowed full scope. He at once began reforms in the army by improving the arms, clothing and sleeping quarters of the troops. For the production of supplies he established military workshops, employing soldiers that had before been idle. The subject of idleness and pauperism engrossed his attention, and he addressed himself to the solution of their causes and the remedy. Schools were established in all the regiments for teaching reading, writing and arithmetic. The soldiers, their children and the peasants were taught gratuitously. As a result, ignorant, idle soldiers became intelligent laborers, proud of their work.

Thompson was the inventor of our modern system of charity organization. Bavaria was swarming with beggars. He proposed to make them industrious and self-supporting; to make them happy first and virtuous afterward. A large building called the House of In-

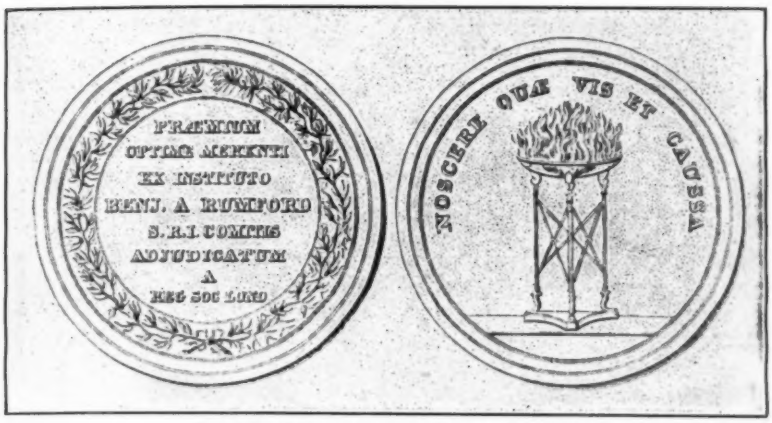
dustry was equipped for spinning and weaving cloth. A series of halls was fitted up for clothiers, dyers, saddlers, knitters, etc. The military workshop besides giving labor to the soldiers at good wages had also paid a revenue to the government. The House of Industry for the poor proved equally successful.

Thompson says, "The beggars not only infested all the streets and public places, but they even made a practise of going into private houses, where they never failed to steal whatever fell in their way. These detestable vermin swarmed everywhere, and they had recourse to most diabolical arts and most horrid crimes in the prosecution of their infamous trade." He had a large building fitted up in the neatest and most comfortable way. The rooms were clean, warm and well



ROYAL INSTITUTION OF GREAT BRITAIN FOUNDED BY RUMFORD.

lighted. Food was served, teachers provided for those who required instruction, and generous compensation for all labor performed. In this asylum for the poor and unfortunate, no ill usage or harsh language was permitted. On New Year's Day, 1790, 2,600 beggars in Munich and vicinity were arrested. Thompson made the first arrest with his own hands; all were treated gently. They were gathered at the town hall and informed that they must beg no more. They were promised comfortable rooms, food and remunerative work if they would labor. His House of Industry and his system of dealing with poverty accomplished what was intended, and mendicity was subverted in Munich.



RUMFORD MEDAL OF THE ROYAL SOCIETY.

His humane and practical methods of suppressing beggary gave him the title of "The Father of the Indigent." While he was dangerously ill, the poor of the city marched in procession to the cathedral and offered up prayers for his recovery. "Imagine my feelings," said he, "upon hearing the confused noise of the prayers, of a multitude of people, passing in the streets, when told that it was the poor of Munich, hundreds in number, who were going in procession to the church to put up public prayers for me—for a private person—a stranger—a protestant."

Thompson's essays on heat and light had been published by the Royal Society in their "Philosophical Transactions." He had been made a member of the Berlin Academy, and of several scientific societies of Bavaria, and later a member of the Institute of France. The elector advanced him to chamberlain, major general, head of war department, chancellor of state, and in 1791 conferred on him the title of Count of the Holy Roman Empire.

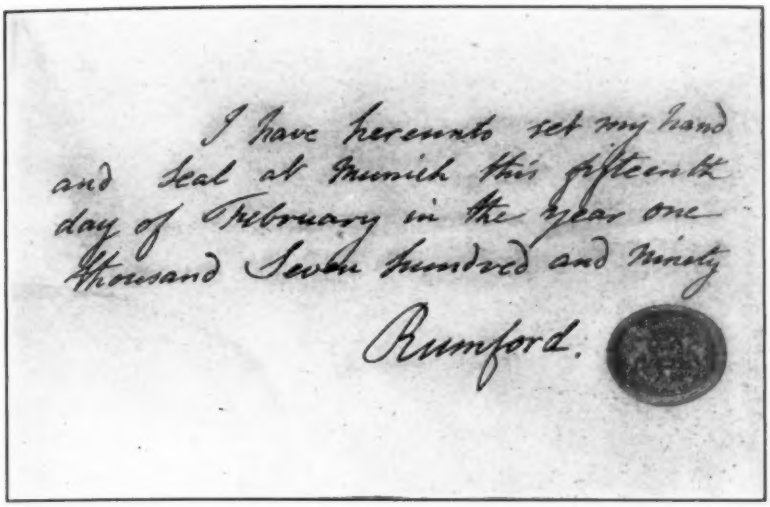
Concord, New Hampshire, was incorporated in 1734 under the name of *Rumford*, and in choosing his title, Thompson selected the early name of the American town where he had lived.

RUMFORD MEDAL OF THE AMERICAN ACADEMY OF ARTS AND SCIENCES.

PORTRAIT AT FORTY-FIVE YEARS OF AGE.

One of the beneficent acts of Count Rumford was that of establishing a public park, called the English Garden. A neglected tract of forest in the environs of Munich that had been a part of the hunting grounds of the elector was by him converted into a beautiful park surrounded by a drive six miles in circuit. Its lovely lakes, walks, grottos, waterfalls and other charming features, are still alluring to a population fond of living in the open air. Within the park is a monument to the memory of its founder, a massive quadrangular structure of freestone. On one side is a bas-relief of Count Rumford in alabaster, below this is the inscription:

To him who rooted out the greatest of public evils,
Idleness and Mendicity, relieved and instructed
the poor, and founded many institutions for
the education of youth.
—Go, Wanderer, and strive to equal him in genius
and activity, and us in gratitude.


I have hereunto set my hand
and seal at Munich this fifteenth
day of February in the year one
thousand seven hundred and ninety
Rumford.

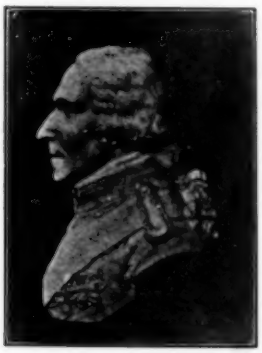
AUTOGRAPH AND SEAL OF RUMFORD.

On the opposite side is the following:

Rumford, the friend of mankind, by genius,
taste and love inspired, changed
this once desert place into what thou
now beholdest.

His health being impaired, he spent more than a year in Italy, and then returned to England after an absence of eleven years. On entering London he met with a terrible loss, which he never ceased to bemoan. While passing St. Paul's churchyard in the evening, his post-chaise was stopped and a trunk containing all his private papers was cut from its fastenings and stolen. He said: "By this cruel robbery, I have been deprived of the fruits of the labor of my whole life and have lost all that I hold most valuable."

Rumford's wife had died in 1792 and his daughter, who was an



PROFILE PORTRAIT. (BAS-RELIEF.)

infant when he left America, now a young lady, joined him in London and lived with him for many years.

He was now forty-two years of age, and the main purpose of his return to England was to publish his essays. Several editions were subsequently brought out in both Europe and America, and they have been translated into German, French and Italian. While on this visit he presented a fund of one thousand pounds to the Royal Society, the interest of which was to be awarded every second year to the author of the most important discovery in light and heat. The society decided that the awards should be made in the form of medals, one of gold and one of silver, which together should contain an intrinsic value equal to the interest.

Rumford, at the same time, gave $5,000 to the American Academy of Arts and Sciences, of Boston, to be used in the same way. In 1837 this fund had increased to $20,000. It has now grown to $59,000 and the annual income is $2,550. Up to 1905, the Rumford premium had been awarded but twenty times. The academy has, however, made a great number of grants of money from the fund to assist those who are making researches in the phenomena of heat and light, and by a decision of the Supreme Court of Massachusetts, a portion of the income from the fund has been diverted to Harvard University. The Rumford professorship of Harvard will be referred to later.

After remaining a year in England, Rumford, accompanied by his daughter Sarah, returned to Munich. Here they occupied a palace supplied with every elegance, convenience and luxury. They were also permitted to use the princely summer residence of the elector, with its extensive park and mountain scenery. His daughter was made countess of the empire and allowed a pension of 2,000 florins for life.

When Napoleon repulsed the Austrians at Friedburg they retreated towards Munich, followed by the French. The elector, delegating Rumford with full authority, left the city, taking refuge in Saxony. Count Rumford at once employed his military talents to meet the emergency. He took chief command of the Bavarian forces, determined to prevent both the Austrians and French from entering the city. The gates were ordered closed and the Austrian forces occupied the opposite side of the river, where they planted their batteries. By a show of force, firmness and presence of mind, he was successful in preventing the occupation of the city by a foreign force.

In 1798 he was appointed Bavarian minister to the court of St. James's. It was a thing quite unprecedented to receive at the English court a subject of Great Britain as a representative of a foreign country, and it was one of the great disappointments of his life when informed that, being a British subject, he could not be received in a diplomatic capacity. He did not receive information of his ineligibility until he had arrived in London in company with his daughter.

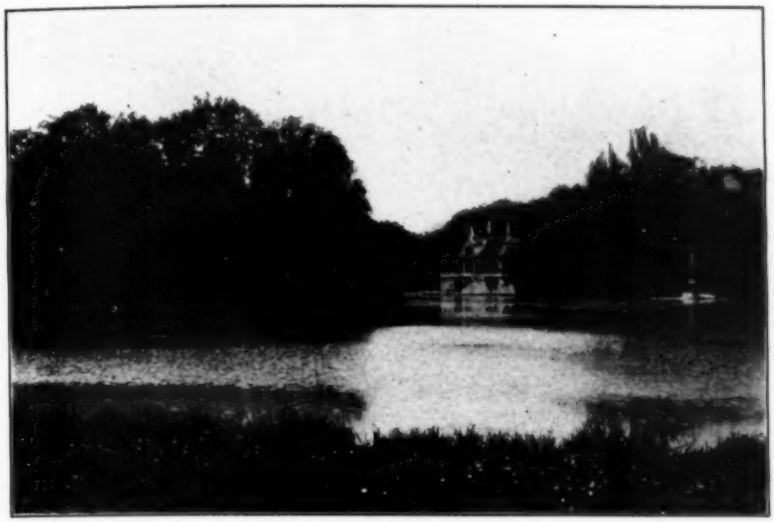
RUMFORD'S STATUE AT MUNICH. ERECTED BY THE KING.

Rumford had always intended to take up his permanent residence in the United States, and he now proposed to establish himself near Cambridge, Mass. He wrote to his friend, Col. Baldwin, to find a desirable property, suitable to his intentions. To encourage his return to his native country, President John Adams instructed the American minister at London to write him as follows:

We have made provisions for the institution of a Military Academy, and I wish to commit its formation to your experience and its future government to your care. In addition, I am authorized to offer to you the appointment of Inspector General of Artillery.

Although his plan to return to America originated with himself, he concluded that his obligations to the Bavarian government were so great and his relations with the institution, which he was now establishing, were so important, that they should not now be relinquished.

MEMORIAL ERECTED TO RUMFORD IN ENGLISH GARDEN.



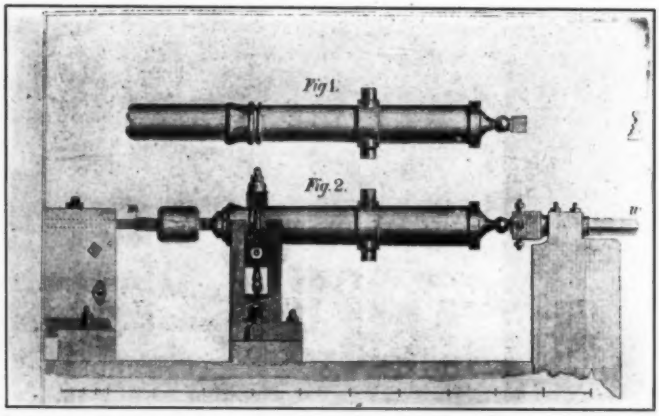
VIEW IN ENGLISH GARDEN.

He had already published a plan for founding a chartered organization to be known as the Royal Institution of Great Britain, its object being the promotion and extension of science and of useful knowledge, and the application of the same to the common purposes of life. The movement at once received the support of the learned men of England; the nobility and the king appeared as patrons.

The charter was granted in January, 1800, and Rumford was appointed the first manager, to serve three years. He had been living at his house in Brompton Row with his daughter, the countess, who now wished to return to America, and, on her departure, Rumford took up his residence in the rooms of the Royal Institution. It proved to be a perfect scientific Elysium for him, being supplied with every implement for experiment that he could suggest.

The founding of this institution was his crowning work in England. It is still a monument to his genius, practical intellectual activity and to his interest in the diffusion of knowledge. He employed Humphry Davy, then little known, as the first lecturer. Faraday afterwards joined Davy and for thirty-eight years was a lecturer there. These geniuses received small compensation at the beginning of their careers. The institution allowed Davy 100 guineas a year and Faraday 25 shillings a week; both were furnished coal, candles and lodging rooms.

The writer was a visitor at the Royal Institution last year and found it a flourishing organization of great influence. The Duke of Northumberland is president and Sir William Crookes, secretary. Among its professors are Lord Rayleigh, Joseph J. Thomson and Sir James Dewar. The laboratories are splendidly equipped for research work,



DRAWING BY RUMFORD, ILLUSTRATING HIS EXPERIMENT AS TO NATURE OF HEAT.

involving the provision of the most costly and complicated apparatus. No institution in the world can boast such a record of original research and important discoveries as that of the Royal Institution for the last one hundred years. Public lectures by eminent investigators are given in the lecture room. Weekly meetings are held by the members. There is a library of 60,000 volumes, and a reading room containing journals, magazines, etc. Here are preserved the historical apparatus of Davy, Faraday and others. Some of the models of Rumford's inventions are to be seen and his portrait, as founder of the institution, appears as frontispiece of the society's pamphlet.

In 1801 war with France had paralyzed industry in England, and Rumford interested himself in practical methods for relieving the poor. On his recommendations, public kitchens were established in all the great towns of England and Scotland. Sixty thousand people were fed daily from the public kitchens in London. The same plan for feeding the poor was adopted in Paris, and the name of *Rumford* was printed on the tickets issued to the poor authorizing them to receive food. In Geneva the tickets contained Rumford's portrait as well as his name. He, at this time, wrote to his daughter—"My greatest delight arises from the silent contemplation of having succeeded in schemes and labors for the benefit of mankind."

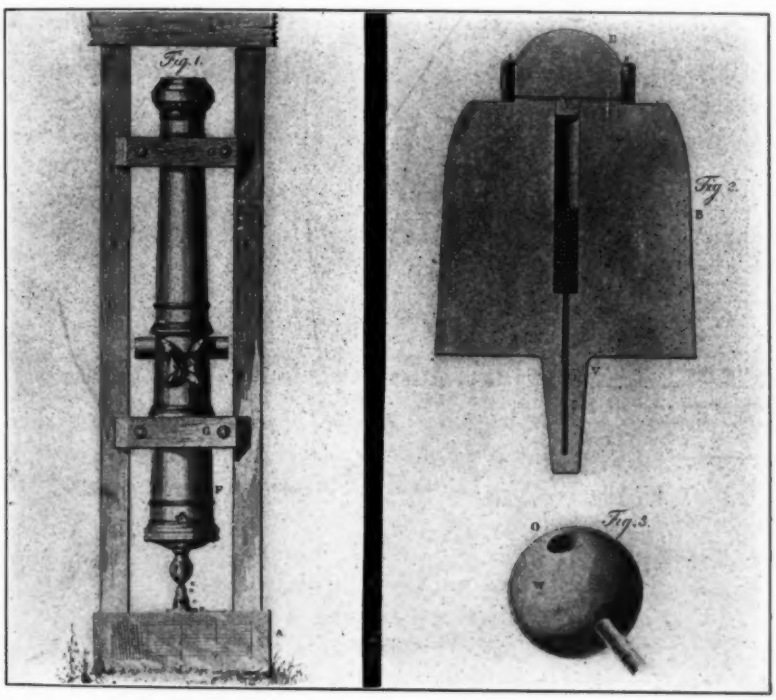
Rumford left England for the last time in May, 1802. His intentions to return were defeated by the obstacles of war, and the next two years were spent between Paris and Munich, finally making his permanent residence in Paris.

He was made a member of the Institute of France, and read more than a dozen papers before that body on the subjects of light, heat, combustion, illumination, etc. His lectures before the Academy of Sciences were beautifully illustrated by drawings of his own execution. Napoleon granted him the favor, as a distinguished man of science, to

reside in France and draw his Bavarian and his English pensions, during the turbulent times of the empire. His reception in Paris delighted him. Parties were given him daily. The new elector of Bavaria wished to make him minister of state, but Rumford preferred to remain in Paris where were centered all that charmed him. His name was known everywhere, and the elector wrote him congratulating him on the cordiality extended to him by the French.

He soon married Madame Lavoisier, widow of the illustrious chemist who had perished, under the guillotine, a victim of the cruel Robespierre. They lived in rue d'Anjou, in the finest part of Paris. The salon of Madame Rumford was the last of the eighteenth century. Lagrange, Laplace, Guizot, Cuvier and Arago were frequent visitors. But the union of Count and Madame Rumford proved unhappy. Their characters and temperaments were incompatible, and after some domestic agitation a separation took place.

Rumford now leased a charming villa at Auteuil, which had been the abode of the celebrated Madame Helvetius, who had made it one of the chief literary centers of Paris, where our own Franklin was a favored guest. Two acres of gardens surrounded the house. It is said that Napoleon, when at St. Helena, recalled a remark made to



DRAWING OF EXPERIMENT WITH GUNPOWDER.

TOMB OF RUMFORD AT AUTEUIL.

him by Madame Helvetius while a visitor at this house. "Ah, General, if you only knew how to be happy within the bounds of two acres of earth!"

Rumford was delighted with his home at Auteuil. His daughter returned to him from America. He was occupied with scientific and literary pursuits, often reading papers at the Academy of France and occasionally making trips to Munich, in the service of Maximilian who had now been crowned King of Bavaria. Here he continued to live

happily until seized with a sudden and violent fever. He expired August 21, 1814, in the sixty-second year of his age.

Baron Cuvier, the count's intimate and confidential friend, perpetual secretary of the French Institute, delivered the Éloge before his associates, in which he said: "It is an honor to France that a man who was held in such high esteem in the two most civilized continents, should choose France for a final sojourn. Here fuller celebrity is most surely awarded, regardless of favors of courts or the freaks of fortune." Here for ten years he had been honored by Frenchmen and by foreigners.

As a philosopher and physicist, Rumford ranks among the greatest of a period that was prolific in scientific research, discovery and invention. Before he began his investigations, the world was in almost absolute ignorance regarding the nature of heat. The metaphysical philosophy of the Greeks regarding the nature of heat, which had remained undisputed for two thousand years, was by Rumford overthrown and the phenomenon established on a mechanical basis. He disproved the theory of an "igneous fluid," or caloric, and conclusively proved that heat could not be a material body. He was the first to point out that energy and heat are mutually convertible, and that both are forms of motion. He was thus the founder of our modern science of thermodynamics.

While superintending the boring of brass cannons in the Arsenal at Munich, his attention was drawn to the great amount of heat acquired by the cannon and the high temperature of the brass chips. He investigated the source of this heat. A blunt borer was pressed with great force against the bottom of the bore hole in the cylindrical riser of a brass cannon. The cannon was rotated nearly a thousand times and the heat developed was sufficient to raise the whole cylinder, which weighed 113 pounds, to seventy degrees, while the amount of metal rubbed off by the borer was only 837 grains. He concluded that the supply of heat obtained from a given quantity of metal was inexhaustible, and hence heat could not be a material substance, but must be "motion."

He had a talent for inventing scientific instruments for making experiments. He thus invented the photometer, an instrument for measuring the relative intensity of different lights; the calorimeter, for measuring the quantity of heat; the thermoscope for indicating the difference of temperatures. He was an accomplished linguist, speaking and writing French, German, Italian and English with equal facility.

Rumford was buried at Auteuil. His monument bears the following inscription:

To the Memory of Benjamin Thompson,
Count Rumford.
Born in 1753 at Concord (?) near Boston, in America;
Died the 21st of August 1814, at Auteuil.
A celebrated Physicist.
An enlightened Philanthropist
His discoveries in Light and Heat have made
his name illustrious.
His labors for ameliorating the lot of the
poor, will cause his name to be cherished
forever by the friends of humanity.
— In Bavaria —
Lieutenant General, Chief of State
Major General, Counselor of State
Minister of War.
— In France —
Member of the Institute
Academy of Sciences.

No mention is made of the honors won by him in England.

In front of the government offices, in that great art center, the city of Munich, is a noble bronze statue of Count Rumford. The figure, clad in the uniform of a Bavarian general, stands ten feet in height. It was modeled by Professor Zambush, and erected by the King of Bavaria at his private expense.

Rumford's income had been a liberal one, but he did not leave a large estate. He was free with money and spent it profusely wherever his interests were concerned. Cuvier said: "Rumford lavished his own money to teach others how to save theirs." Both his mother and daughter were, by him, supplied with annuities, and at one time he sent his mother $10,000 to be used as she pleased.

The Count's last will was executed in 1812. Lafayette signed it as a witness. After providing for his daughter, he bequeathed to Harvard University an annuity of $1,000, and also made that university his residuary legatee. The bequest was for the purpose of founding a professorship to teach the utility of the physical and mathematical sciences. The capital sum received by Harvard University from the Rumford estate was $28,395. This has been increased until the "Rumford Fund" is now $56,441. The professorship was established in 1816. A fine portrait of Count Rumford hangs in the room of the Faculty of Arts and Sciences, No. 5, University Hall.

In the summer of 1906 the writer made a pilgrimage to the grave of Rumford. After passing the fine statue of Franklin, in the Place du Trocodero, the rue Franklin was followed to the rue de Passy, thence to the rue Mozart, which leads directly to Rumford's house in the rue d'Auteuil. While ambassador to France, Franklin traversed these streets many times to visit his friend Madame Helvetius, who then lived in the house later occupied by Rumford. In his "Dialogue

between Franklin and the Gout" Franklin is accused of taking too little exercise. Gout says: "Behold your fair friend at Auteuil. . . . When she honors you with a visit, it is on foot. In this see at once the preservation of her health and personal charms. But when you go to Auteuil, you must have your carriage, though it is no farther from Passy to Auteuil than from Auteuil to Passy."

Rumford's house appears to be much as it was one hundred years ago, although shorn of its two acres of gardens and now with shabby exterior. The front is enclosed by a high iron fence, with heavy gates and there still remains a suggestion of shrubbery and flowers. In 1870 this house was the scene of a tragedy in which Prince Pierre Bonaparte shot and killed Victor Noir, a young journalist, who had presented a challenge.

Half a mile southward in the Rue Michel Ange is the cemetery of Auteuil. It is surrounded by a high wall and contains probably more than half an acre of ground. The graves are much crowded and the paths narrow. No interments are now made there. The tomb of Count Rumford is near the south wall. The horizontal stone is perhaps six feet square; the vertical stone of about the same dimensions, and three feet thick. The material appears to be a soft marble, now so badly weathered that the inscriptions are illegible.

HYPOTHESIS OF RADIANT MATTER[1]

By MORRIS LOEB, PH.D.

THE enormous literature which has developed from the discovery of radium and from the study of cognate phenomena has made it increasingly difficult to form a calm opinion upon the merits of all the claims which have been advanced, and upon the validity of the theories which have been based upon them. Undoubtedly, the great bulk of the experimental data is exact, although time may show that some of the experiments which were recorded before the technique was fully developed may require correction. Without questioning in the slightest degree the experiments reported by some of the skillful observers of modern times, one is, nevertheless, permitted to hesitate in adopting hypotheses that not only subvert formerly accepted ideas, but also seem, in many cases, inconsistent with one another.

The chemical world has been accused of accepting too dogmatically the theory of the conservation of matter, the indivisibility of the atom, etc. Ought we not, then, to guard ourselves against a similar fault in adopting newer views?

I propose to take up seriatim the methods of reasoning which have led to the present hypothesis of radiant matter as expressed by its chief exponents, and to indicate some points which seem to me to be inconsistent with older views, or in conflict with one another; and I shall begin with what may, from the present point of view, be called a static phenomenon, the behavior of the atom toward light. It is known that Lorentz modified Maxwell's electro-magnetic theory of light, by assuming that the vibrations from which light-waves originate are not produced by the atom as a whole, but rather by the vibration of its positive or negative electric charge, conceived as a special entity, which we may now personify, as it were, by the more recently coined name electron. The electron vibrates in an elliptical path which is really the result of two circular oscillations in opposite directions, and of differing amplitudes, but of identical period. An alteration of the radii of these circles would merely alter the shape of the ellipse; but if the *periods* of the two circular motions were made to differ, no single resultant could appear, for the two vibrations would produce waves of different length, *i. e.*, light rays of different refrangibility. Now, a magnetic strain

[1] Extracts from a review presented to the New York Section of the American Chemical Society at its meetings, November, 1907.

ought to exert some influence on an electron; if it accelerated its dextro-gyratory motion, it would retard its lævo-gyration, or vice versa. This is precisely what Zeeman found when he examined the emission-spectra of vapors that were placed in an electro-magnetic field; single lines are broken up into two or more finer lines, placed symmetrically with regard to the position of the original one. Righi has generalized the reasoning so that it covers practically every relation between the vibrating electron and the external magnetic strain to which it is subjected, and reaches two conclusions: First, the vibrating electron is electro-negative; second, the ratio e/m, *i. e.*, electric charge over mass, is about 1,000 times as great as the ratio between the electric charge and mass of the hydrogen ion. Assuming, perhaps arbitrarily, that the electric charge is the same, the mass of the electron is about 1/1,000 that of the hydrogen ion; it can be no mere coincidence that Thomson, Kaufmann and others arrive at virtually the same figure for the mass of the corpuscles which carry the negative charges in ionized gases of whatever chemical constitution; in fact, everybody recognizes their identity.

To quote Righi, the neutral chemical atom (as distinguished from the ion) consists of a central mass of positive charge, around which revolve as satellites one or more electro-negative corpuscles, retained in their orbits by some centripetal force.

In connection with this definition, the following points seem to require emphasis: the number of electrons per atom are few, practically corresponding to the valency; this seems to be corroborated by recent experiments of Becquerel on the phosphorescence of uranium minerals at low temperatures, which likewise point out that light-emission is not always confined to the negative corpuscle, as Righi would have it. The total mass of the free electrons in an atom is not sufficient to affect the ratio between specific heats for constant pressure and constant volume of monatomic vapors, like mercury and cadmium; their velocity in their orbits does not approach that of light, and they have no high momentum retained by comparatively powerful internal attractions. These electrons can not be identical with the X-particles which are projected with terrific force from the uranium, radium and other atoms, according to Rutherford and his followers.

I need only touch briefly on the electric discharges in vacuum tubes: it is generally accepted that we distinguish Lenard or cathode rays, which are negative, and positive Goldstein or canal rays within the tube. They can be deflected by electric or magnetic fields, they produce mechanical and heating effects, cast visible shadows, etc., and they behave in general like streams of actual particles charged with electricity. When the cathode ray strikes an impenetrable obstacle, like glass, the X-rays are produced as a secondary effect: these do not behave as if conveyed by neutral particles; have vast penetrating power; contain no electric charge, as they are not influenced by magnetic or elec-

tric fields, and are neither refracted nor reflected. I would emphasize, however, their ability to discharge an electrometer, as well as to influence the photographic plate. Their peculiarities have been recently ascribed to the fact that they represented aperiodic impulses given to the luminiferous ether—which conveys no meaning to my mind, excepting that they can *not* be explained by the undulatory theory. The velocity of the canal rays has been determined, and the mass of their hypothetical particles measured by the amount of their deflection in magnetic fields of varying strength; both values approximate those found for the ordinary chemical atoms or molecules; in the case of the negative cathode rays, however, the velocities and mass correspond to those assumed for the electrons. I confess to a serious difficulty in harmonizing the notion of a corpuscular structure of the atoms with the explanation given by the same school for the need of high vacua for the production of cathode rays. It is said that the electrons must have a considerable free path in order that they may travel with undiminished velocity toward the anode: but if the atoms, instead of being compact elastic bodies, be mere nebulæ of electrons, the relation of whose sizes and interstices is comparable to that of the molecules in a normal gas, it follows that a free electron, hurled vehemently forward from the cathode, could pass quite through a number of atoms without collision with any of their constituent corpuscles; the free path of the electron is so enormous, on this hypothesis, that the order of its magnitude could not be materially affected by the degree of rarefaction of the gas customary in the Crookes tube.

We must recollect, however, that the hypothesis, first elaborated by Larmor, that the electrons are the primordial constituents of the atoms, does not, like that of Prout, simply extend the limits of the divisibility of matter. The electron is not to be considered as a small speck of matter at all, but as a permanent manifestation of energy concentrated on a minute portion of the luminiferous ether. This view and the explanation of many phenomena on such a basis has been acclaimed as the triumph of energetics, the final elimination of the conception of matter. An unbiased reading of J. J. Thomson's Yale lectures, however, will impress anybody that he decidedly *materializes* both energy and ether. Perhaps much of this materialization is purely symbolic, to bring his mathematical reasoning within the comprehension of his audience; but to me it seems that an electric charge which has quantity, mass, inertia, elasticity and expansibility, which obeys the laws of hydrostatics, and virtually has a surface beyond which it can only produce effects by the medium of mysterious lines of force, has a marvelous resemblance to the picture which the ordinary chemist's mind would form of material substance. His ether is not only that puzzling paradox, at once impalpable and inconceivably dense, rigid and frictionless, which we have accepted as the whole means of explaining the

transmission of motion through a vacuum; to extend its importance as the substratum of *all* phenomena it must become heterogeneous and capable of deformation; to form a neutral atom, some of it must become a spherical jelly in which other parts of itself are imbedded as rigid particles. It has, consequently, different degrees of hardness, and is subject to internal attractions. Thomson even volunteers the admission that, for the explanation of certain phenomena, his ether must have structure, or, at least, be stratified.

This can, of course, be no insinuation against the work of some of the greatest living physicists and mathematicians: accepting their premises, I do not doubt that they have drawn the consequences in the most rigid fashion. I do assert, however, that some of their fundamental terms are used in a different sense from that to which we are accustomed, and that we are, therefore, entitled to doubt whether the conclusions which they reach really affect the phenomena with which the chemist deals: as if one were to discuss the crystallographic structure of Pentelian marble with reference to the architecture of the Parthenon.

A few examples, pertinent to our inquiry, will more precisely establish my meaning. One of the fundamental postulates of Professor Thomson's mathematical argument is the definition of momentum as the product of mass by velocity. Although this is not axiomatic, we accept it as such by reason of the many ballistic experiments which have proved its truth, so long as the projectile's mass was assumed to remain constant: we should hesitate if we were told that mass was to vary, *i. e.*, that a bullet which weighs the same before and after the shot, was heavier during its flight. But the momentum of Thomson's electrons increases faster than their velocity, when the latter approaches that of light; hence, he says, the mass of the electrons increases with their swiftness. True, he calls it an electro-magnetic mass, but some of his followers have forgotten the distinction. At all events, his terms momentum and mass must not be accepted by us in their usual meaning.

It is perfectly true that Thomson's calculations are corroborated by Kaufmann's experiments on the velocity of radium rays in combined electric and magnetic fields, if the latter's data are calculated according to Thomson's views; without even seeking a radically different basis—which would not be difficult—we can follow Thomson to a point where his departure from ordinary assumptions becomes evident. He shows that the value e/m diminishes at high velocities and then he assumes that e, the electro-static charge, is constant; therefore m, the mass, varies. Now, the value of e is derived from Faraday's law, which would never have been announced if Faraday had not dealt with the equivalent weights as fixed mathematical quantities. In fact, just so far as Thomson substantializes electricity by giving it atomic structure, with invariable mass, the chemical atom becomes wavy and matter

evanesces into the ghost-like form which energy has assumed in the chemical mind. If our scientific terms are, as it were, to receive the reciprocals of their present significance—progress may ultimately result, but we should enter into topsy-turvydom with our eyes open.

The electron theory possesses the merit of furnishing a working hypothesis upon which to coordinate the various electrical phenomena of vacuum tube and radio-active origin: chief among which is the increased conductivity of gases. Either direct current measurement or the more sensitive electrometer, determinative of the decrease of electro-static potential, indicates that gases begin to conduct electricity when affected by ultra-violet light, by cathode and X-rays, by radium, thorium, etc. Ingenious experiments have proved that portions of the gas are positively, others negatively, charged; that they behave as if ionized; the numbers, masses and charges of the hypothetical ions have been measured and found to agree with the assumption that the negative ions have the magnitude of the electrons, the positive ions that of the regular molecules, *i. e.,* the negative ions are always very small and mobile, with the same value for all gases; the positive ions are, at least, 1,000 times as large, and vary for different gases. If the gas moves away from the locality of ionizing influence, its conductivity disappears gradually at a rate to suggest reunion of the ions. Plausible, if not quite conclusive, reasoning connects the ionization hypothesis with the novel phenomenon of the saturation constant; viz., the fact that the flow of electricity through a conducting gas increases proportionately to the voltage between the electrodes up to a maximum, when further increase of potential has practically no effect on the current. This saturation current, it may be remarked, is used to characterize radio-activity; it is admittedly a complex phenomenon, and I should be inclined to lay more stress upon the qualitative than the precise quantitative results obtained in a number of recent experiments.

Those who, like Armstrong, oppose the electrolytic dissociation hypothesis of Arrhenius, naturally attack the ionization hypothesis with still greater vehemence, and I believe that this will be the battleground of opposing theories for some time to come. As the phenomenon is distinctly a secondary reaction, from our point of view, we need not discuss it in its various aspects, beyond noting that even without detectable radio-active agencies the atmospheric air conducts electricity to a slight extent, varying with location, as well as with the hours of the day.

The radiations from the active chemical substances present a very complex aspect; besides light and heat, radium and its congeners send out α, β and γ rays, respectively electro-positive, electro-negative and neutral when tested in electric and magnetic fields.

From radium α rays are sent out about four times as abundantly as β rays, the γ variety being relatively few. α rays are electro-positive,

have a speed one tenth of the velocity of light, and a molecular mass of atomic magnitude. They penetrate a few centimeters into air, pass through thin aluminum foil but are stopped by denser metals. As they are but slightly deviable in a magnetic field, their momentum is calculated to be enormous: until, however, better evidence of the total positive charge which they carry has been obtained, we can not consider the magnitude of the momentum as definitely established; especially since their speed does not appear to be uniform. From experiments wherein α particles are allowed to escape freely, and again restrained by a lead cylinder surrounding radium, much of the apparent heat of the latter body appears to be due to the impinging of the α rays upon the surrounding surfaces.

β-Rays are similar to cathode rays; they are less absorbable than the α variety, and proceed at various speed, many approaching the velocity of light; they are stopped by solids in proportion to their density.

γ-Rays are similar to X-rays, of great penetrating power, and they are thought by some to be secondary effects of α and β rays, just as the X-rays originate from the impact of cathode rays on the glass wall of the Crookes tube. Besides, we have a multitude of conflicting accounts of secondary tertiary rays, resulting from these three varieties.

The chief method of research is the study of ionization, with the interposition of screens and magnetic fields, to separate the different kinds of rays. On the other hand, the varieties of rays emitted, their relative strength, and their variations of intensity, are the characteristics upon which the identification of the various so-called transformation-products of radio-active material is based. I have, therefore, copied from Professor Rutherford's book[2] tabulations of these properties.

With regard to these various transformations, we should realize that the majority of the names are titles of hypothetical substance, whose existence within certain mixtures is assumed upon the evidence of their momentary radio-activity. The only one really isolated is that emanation which has all the properties of a gas, including that of condensibility at low temperatures—with the exception that its liquid form shows no vapor pressure—but has in addition remarkable energy effects, and has, undoubtedly, undergone transformation in Ramsay's hands. Bearing in mind the infinitesimal quantities of emanation which Ramsay and his associates could obtain, we are alike astounded by their marvelous manipulative dexterity and by the nature of their observations. First we had the gradual appearance of helium, when the emanation was stored by itself; then came the appearance of neon, when the emanation came into contact with water, the latter being partially decomposed into oxygen and hydrogen; lastly the partial reduction of copper nitrate solution, with the simultaneous appearance of lithium,

[2] "Radio-activity," 1905.

TRANSFORMATION PRODUCTS OF THORIUM, ACTINIUM AND RADIUM ACCORDING TO RUTHERFORD

Product	Time to be half transformed	Radiations
Thorium	——	α rays
↓		
Th. X	4 days	α rays
↓		
Emanation	54 seconds	α rays
↓		
Thorium A	11 hours (Active Deposit)	no rays
↓		
Thorium B	55 minutes (Active Deposit)	α, β, γ rays
↓		
?	——	——
Actinium	?	no rays
Actinium X	10.2 days	α (β and γ)
Emanation	3.9 seconds	α rays
Actinium A	35.7 minutes	no rays
Actinium B	2.15 minutes	α, β and γ
Radium	1,200 years	α rays
↓		
Emanation	3.8 days	α rays
↓		
Radium A (Active Deposit of Rapid Change)	3 minutes	α rays
↓		
Radium B (Active Deposit of Rapid Change)	21 minutes	no rays
↓		
Radium C (Active Deposit of Rapid Change)	28 minutes	α, β, γ rays
↓		
Radium D (Active Deposit of Slow Change)	about 40 years	no rays
↓		
Radium E (Active Deposit of Slow Change)	6 days	β (and γ) rays
↓		
Radium F (Active Deposit of Slow Change)	143 days	α rays
?	——	——

while the emanation underwent a change into argon. The lithium, we are assured, could not be found in the original materials; it represents about .01 per cent. of the sodium and calcium found in the same experiment; its actual amount, after correcting a slight oversight in Ramsay's estimate, would be 0.00000003 gram. For such a quantity the amount of copper transformed would be too minute for the detection of a loss from the 0.3 gram of copper which the original solution may be assumed

to have contained: but, until a loss of copper be ascertained, to correspond with the gain in lithium, it appears to me that the assumption of transformation is premature. Ramsay found that this solution contained in all 1.67 mg. alkaline chlorides, chiefly sodium chloride; while 0.79 mg. were produced in a blank experiment, when the emanation was excluded. While this latter amount is admittedly derived from the glass bulb, the excess obtained in the presence of emanation is ascribed to the degradation of the copper, neglecting the fact that this second solution must have been fairly acid and would, therefore, have attacked the glass more vigorously. Accepting his suggestion, however, the deficit of copper ought to approach 0.8 mg., an amount which ordinary analysis can detect. We may, therefore, hope that further experiments by Professor Ramsay will throw light upon this side of the subject.

Of Ramsay's present conclusion, the following résumé may be given: Emanation is a gas of about atomic weight 216.5, derived from radium, of atomic weight 225, simultaneously with α-particles which are *not* helium. When emanation and the α-particles are shut up together, the bombardment of the latter breaks up the emanation into helium; but if heavier molecules, like water, be present, they receive some of the bombardment, and the emanation is only degraded into neon; the pressure of copper nitrate still further protecting the emanation, so that it only breaks down to argon. This kinetic explanation is not impeccable; for, according to the principles of mass-action, the preponderance of water molecules in the copper nitrate solution, as well as the predominance of hydrogen and oxygen in its decomposition products, would imply the presence of considerable amounts of neon to accompany the argon. As neon is said to be absent, we must either seek for some other hypothesis or explain how the neon reverts to argon after it is once formed.

Ramsay's views contradict those of Rutherford and others, who seek to identify helium with the α-rays, and the latter would thereby lose a good deal of their substantive character. Furthermore, it is to be noted that the α-particles bear positive charges: if they were merely chemical atoms, such a charge might possibly be obtained as they tore themselves loose from the larger complex, during radiation; but if they be non-substantive masses of free energy, it will be difficult to reconcile the various assumed transformations with the electro-chemical properties, valencies, etc., of the elements in question.

It must be recalled that Rutherford does assume that the successive transformations of radium, for instance, are effected by the expulsions of the α-particles and that these have *atomic* mass: an atom of radium, therefore, contains a finite number of them. As the transformations are atomic and not molecular, Rutherford's application of the mathematics of mass-action can mean but one thing: that the various rates of transformation depend upon the chances of encounter and relative

positions of the particles *within* the atom. These rates, however, as measured by the period of decay, vary from thousands of years to a few seconds for the different educts, and that irregularly in the order of transformation—such great differences could only be explained by an infinite number of components, with large free paths, electrons, in other words. It would then remain to be shown what caused a certain great number of negative electrons to form an electro-positive α-particle, and become expelled with great violence from their surroundings.

Naturally, the failure of a hypothesis to explain certain facts does not invalidate the latter. Rutherford's brilliant analysis of the curves of increasing and decreasing ionization and the agreement observed with calculated results prove that he is not dealing with mere fortuitous coincidences. Many of his conclusions seem incontrovertible upon his premises; but here again, the *advocatus diaboli* must step in and ask whether the premises are axiomatic: two of them appear to me to be doubtful. (1) A curve of decay is based on electroscopic measurements upon the tacit assumption that the rays sent out by that particular phase are always the same; but we are told that both α and β rays vary greatly in speed and momentum, hence neither variety would show a uniform ionizing power; assuming that a substance did send out α rays for a long time, but that their velocities were gradually reduced, would not the ionization indicate a more rapid decay than was really the case? (2) It is practically assumed throughout that ionization is directly proportioned to the amount of radio-active material present: but this remains to be proven. Where layers of any density are involved, we know that it is not true, owing to internal absorption, etc.; for ideally thin layers, weighing and other measurement are out of the question.

I do not think that this latter objection ought to be dismissed lightly, when we find such a phenomenon as the almost universal ionization of the atmosphere ascribed to the presence of radium or its educts. Thomson himself has shown a variety of ways for ionizing air, when any variation in the amount of radium present—or, rather, absent—is out of the question; some of these serve particularly well to explain the phenomena in the open air. Recently, indeed, quite a number of investigators have observed diurnal variations in this atmospheric ionization, sufficiently marked to require some other explanation than the production of emanations from the earth or surrounding materials. Gustave Le Bon, in his "Evolution de la Matiere," shows how the gold-leaf electroscope is discharged when connected with some very dry sulphate of quinine, which is taking up hygroscopic moisture. Are we ready, with him, to assume that the quinine is catalyzing some atoms into nirvaña, or that the electroscope may indicate many changes that are not intra-atomic?

THE NEW PHILOSOPHY CALLED PRAGMATISM

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PRAGMATISM is a recent movement of thought which is seeking to do justice to the neglected claims of common sense, of religious faith and of science, in determining a true philosophy of life. It is, as Professor James says, simply a new name for some old ways of thinking, yet in its scope and depth of significance it promises to rank among the important and characteristic products of our Anglo-Saxon civilization.

Pragmatism originated as a logical principle of method, first formulated by Mr. Charles Peirce in 1878 in an article published in The Popular Science Monthly. Twenty years later, Professor James, in an address before the Philosophical Club of the University of California, brought Peirce's principle to the attention of the philosophical world, since which time those sympathetic with the general point of view have been rallying about it as an organizing center.

At the present time pragmatism is connected with the names of three men, in this country and in England, each being associated with a distinct phase of the movement. Professor William James, of Harvard University, emphasizes the practical meaning of philosophy for every-day life. Mr. F. C. S. Schiller, of Oxford University, England, defends the rights of religious faith and feeling in determining our beliefs. Professor John Dewey, of Columbia University, is the champion of a scientific empirical method in philosophy. Professor James uses the words pragmatism and radical empiricism to describe his point of view. Mr. Schiller prefers the term humanism and his philosophy has much in common with what in other quarters has come to be called personalism. Professor Dewey's method is quite generally known as instrumentalism, but in a recent article is described by Professor Dewey himself as immediate empiricism.

These three leading exponents of pragmatism may be regarded as meeting the objections urged, respectively, by the man of affairs, by the mystical religious man, and by the man of science.

The man of affairs has objected to philosophy in the past on the ground of its being abstruse and theoretical, impractical and dreary. He is unable to convert the speculations of the metaphysician into market values, on the one hand—it doesn't "bake any bread"—while, on the other hand, it unsettles his faith in the spiritual verities—"God,

freedom and immortality"—belief in which he regards as essential to his peace of mind.

The answer which pragmatism makes to this objection of common sense is to admit its main contention. Concrete experience must, in the last analysis, be the test of the truth of ideas, and philosophy in the past *has* been out of touch with the interests of practical life. As Mr. Peirce and Professor James put it, there is no difference which does not *make* a difference. The test of theories must be found in practise. The pragmatic philosophy is a renewed emphasis of this truth. It is a philosophy of doing, and of knowing, only in relation to doing. It is a philosophy of work, of activity, of enterprise, of achievement. And for this reason it has taken up arms against all forms of transcendentalism and absolutism and dogmatism and apriorism in so far as these stand for intellectual interests which do not grow out of or minister to the needs of life.

But the pragmatic philosophy has one trenchent criticism to make on the attitude of the man of affairs—he stands in his own light, stands so close to his practise that he loses perspective, holding a nominal theory which does not correspond with the real theory of his practise. His attitude is essentially uncritical and primitive—naïve, total, implicit, rather than reflective, discriminating and definitive. In becoming practical, philosophy deals common sense a severe blow by showing its inconsistency and the narrowness and vulgarity, often, of its empiricism—for, after all, theories, while not action in an overt sense, are yet themselves just refined forms of adjustment in a complicated environment.

Another type of person, impressed deeply by the so-called spiritual things of life, by the values as opposed to the facts, believes that the realities which are of most worth are apprehended through the feelings and by faith rather than by purely logical processes, and objects to philosophy on the score of its being artificial and arbitrary, substituting formulas for vital experience and abstract propositions for warm concrete appreciations of things. This is the essentially mystical attitude which includes, not only the religionist, but the artist and many others who distrust the purely intellectualist way of looking at the universe.

Here, again, pragmatism admits the main contention of the objector. Philosophy too often, as Mr. Bradley says, is the finding of bad reasons for what we believe upon instinct, and a substitution of abstract impersonal laws for the living personal values of immediate experience. And this new philosophy called pragmatism is trying to so reconstruct the intellectual machinery as to meet the needs of this deeper emotional and volitional nature of man. In so far as pragmatism emphasizes the personal as opposed to the purely formal conditions of thinking, it may be described as mystical in the legitimate and good sense of the word.

This is the core of the humanism of Mr. Schiller. Faith underlies

the hypothesis of scientific method as truly as the act of obedience in religion—not, however, in the sense of the child Mr. Schiller quotes, who says that faith is believing what you know isn't true, but in the sense rather of a legitimate speculation where all the factors are uncertain, in the sense of a prudent gambling or betting on your partial knowledge. If faith lies at the basis of our credit system in business and is the only sanction of the inductive leap in scientific generalization, why should it not be legitimate to take the risk of there being a God or a future life? For all we know, the wish and the will to believe may be a factor in determining the reality—as he who thinketh his friend to be true maketh him true.

Pragmatism, in this respect, is a protest against the cold intellectualism of the philosophy and science of the age. In mastering the means of living we have forgotten the ends of life. We confuse money with wealth, the church with religion, politics with government, the school with education, leisure with culture. But he fails in the having who spendeth his days in the getting. The values of life, as Hume long since taught us, lie in the alogical forces of the soul. Reason and the ratiocinative processes find their only justification in serving at once to satisfy and to modify the feelings and desires which underlie all other aspects of personality.

But still a third objection is frequently raised to philosophy by the man of science, and the pragmatic reply to this is contained in the new instrumental or functional theory of knowledge of Professor Dewey and his school. The man of science criticizes philosophy for being too theoretical in the sense of speculative, "not sticking to the facts." The metaphysician is prone, he says, to spin a universe out of his own inner consciousness, and tries to make the facts fit this ideal system. Once again, pragmatism meets the objector by admitting the force of his objection so far as past systems of philosophy are concerned, and seeks to win the cooperation of the scientist in constructing a philosophy which will be scientific in its method.

But the pragmatist reminds the man of science that he is not free from speculation in his own enterprise, that indeed hypothesis is one of the leading instruments of scientific research, while his whole procedure is shot through and through with metaphysical presuppositions which are the more prejudicial because unsuspected. The aim of a pragmatic philosophy is to bring metaphysical speculation to the test of scientific exactness, on the one hand, and, on the other, to help the scientist to bring to clear self-consciousness his own logical assumptions. This involves, not only a new conception of philosophy, but a new conception of science in relation to philosophy.

The wings of metaphysical speculation are clipped, but philosophy no longer is relegated to the left-overs. Its subject-matter as ordinarily conceived is the methodological scrap-heap of the scientist. All the

residual problems which science shoves aside as unimportant or irrelevant are turned over to philosophy, which, as the various sciences successively split off from the parent-stem, has to be satisfied with the vague chaos of general opinions which have not yet come under scientific scrutiny. On such a view philosophy, of course, never can hope to occupy a position of dignity in the intellectual world, for as soon as the human intellect takes up seriously one of these remaining problems and subjects it to careful experimental study, it ceases to be called philosophy and is scored to the credit of science. The result is that the field of philosophy becomes more and more restricted until finally science occupies the whole field and philosophy has only a historical significance.

The name, to be sure, is unimportant—whether it be called philosophy or science—but the fact is that as science gradually encroaches upon the field of the so-called philosophical subject-matter, her method has been becoming more and more philosophic: that is to say, with the progress of science it becomes increasingly necessary to go beyond the confines of any particular science in order to explain any one of its facts. Hence the appearance of the hyphen-sciences and of the comparative method, which have grown up in the interstices between the sciences as formerly classified. Now, in so far as an explanatory law extends beyond the province of the particular science, it is what, in the history of thought, has been called a philosophical principle, and inasmuch as science to-day is increasingly comparative in its method, it follows that it is becoming increasingly philosophic. Instead of philosophy being condemned to the unclassified residuum, it is becoming the very methodology of science. Each scientist is perforce becoming philosophic in order to understand the implications of his own procedure. It behooves the man of science to realize this, and it behooves the old-fashioned metaphysician, who supposes that his method is distinct from that of science, to realize that the only fruitful philosophizing that is going on at the present time is at the hands of the philosophic scientists and the scientific philosophers.

One of the main contributions to this new conception of the relation of philosophy to science is contained in the instrumentalism of Professor Dewey. The main contention of this theory is that ideas are instrumental to action: they are secondary, derived *from* action, and they are teleological, dynamogenic, point forward *to* action; or, in so far as they win a permanent place for themselves as ideas, it is because they are more delicate types of action-systems. The reflective or mediating modes of experience are instrumental to the immediate forms of feeling and conduct.

It follows that the formal logic which was elaborated out of relation to the emotional and volitional needs of life, and is consequently correct only in so far as it remains abstract, and valid only in as much

as it refers to nothing in particular in the world of concrete values—it follows that this logic will not meet the requirements of a scientific method which is seeking to explain the actual world of phenomena conditioned by human interests and purposes.

Instrumentalism, in other words, is an attempt at once to make philosophy scientific and science philosophic, and pragmatism means instrumentalism in this sense. In seeking to work out this relation in detail, pragmatism has become a general theory of experience, and, interpreted in terms of existing schools of thought, may be described as presenting both an empiricistic and an idealistic phase of its methodology.

In the first place, pragmatism is empiricistic. If philosophy is to be practical and personal and instrumental it must begin with concrete experience, not with an assumed reality beyond nor with an abstracted aspect. It must begin with the full tide of life as we live it and try to understand it from within, not seek to leap out of experience to some transcendental vantage-ground from which the procession might be watched from without. Nor will philosophy begin with such partial aspects as mind and matter nor with such terminal problems as origin and destiny, but will endeavor by a patient study of the way in which experience goes on in the present moment of consciousness to construct the law of the process by which it goes on in other moments. This is the empircal principle of pragmatism. As Professor Dewey puts it, Reality *is* what it is *experienced as*. Or as Hegel long since phrased it, "the laws of thought are the laws of things."

This empirical point of view has several important implications. It implies, for one thing, that the distinction between experience and reality is not an absolute one, not an ontological distinction, as the metaphysicians say, but only a methodological or functional one. It no more represents a distinctness in existence than does the distinction of the how and the what of anything, or the distinction of process and content. Experience regarded from the point of view of what it *is*, its content, its filling of objects and events, we call reality. Reality, regarded from the point of view of *how it goes on* or the way in which it occurs in consciousness, that is, viewed as a process of evolution here and now, we call experience. A moment of consciousness is a sample of how reality evolves. An object in space or an event in time is a sample of the content of this evolving process. Reality viewed in longitudinal section as a process gives us what we call experience. Experience taken in cross-section yields a content which we call reality.

In the second place, mind or consciousness *is* what it *seems to be*—a transformation-phase of experience, not a separate entity. The distinction of mind and body and their alleged disparateness and supposed parallelism is a pseudo-problem created by the methodological inutil-

ities of a prejudiced metaphysics. Just as the hypostatizing of the distinction of reality and experience gave rise to the tedious detour of the epistemological problem, so the erection of the practical distinction between the psychical and the physical into an ontological chasm has produced the paradox of mind and matter in metaphysics. Aristotle's doctrine of entelechy was nearer the truth, which sought to define what a thing *is* in terms of what it *does,* in terms of its behavior and functions, and in terms of how it came to be what it is, its genesis and growth. Consciousness, the mind, the soul, is to be defined as a physical object is defined in science: a molecule or an atom is defined in modern physics as the sum of its attributes, the synthesis of the relations in which it stands. Consciousness no longer may be regarded as an entity, nor as the attribute of epiphenomenal manifestation of an entity; it must be defined, as everything else in modern science, as a relation or system of relationships. Reality, Lotze said, means standing-in-relations, a thing *is* where it *acts,* being is doing. If this is true, then consciousness is what it seems to be—a transition phase of the contents of experience under certain conditions in which they are undergoing reconstruction into something else. It is not a different kind of reality nor a permanent parallel aspect of material existence, but a mode of experience in the phase of metamorphosis into further experience.

A third implication of this pragmatic empiricism concerns our relation to the making of reality. There is a sense in which reality is *given* and a sense in which it is *made.* As Mr. Schiller says, you may "find yourself in love" or you may "make love." You may wish for a chair and find one or have one given to you, or you may wish for a chair and invent one, make one. Is reality discovered or created by knowledge? Are the objects which form the content of experience revealed or constituted by consciousness? This is one of the age-old problems of philosophy which have divided thinkers into transcendentalists and empiricists, nativists and evolutionists. Taking the two terms of the distinction abstractly, it seems that in the final analysis something must be absolutely given, on the one hand, yet, on the other, that something is absolutely created. It appears that there is nothing new under the sun, and yet that everything changes. If all is given, then the apparent progress and freshness of our feelings is an illusion, and if any single part of experience is absolutely given, the whole must be given, as the absolute idealists have been logical enough to see. On the other hand, if all is created, what is to save us from solipsism? The answer is, that neither term of the distinction is to be taken abstractly. *Given* means *taken as given* for the situation, while *made* or created means produced anew *relative to some interest* or need, not created *ex nihilo.* Our givings and takings, our acquiescences and imperatives, are not ultimate and abstract, but relative in the sense of

relevant to the proximate needs of concrete issues. Taken abstractly, these complementary principles have significance only as limiting concepts, like the infinite and the infinitesimal in mathematics; they are signs of operations to be performed, not absolute realities blocking progress. There is no experience in general or in the abstract, no absolute experience; experience is always in specific centers of concrete interest and value. Hence questions of the absolute origin or absolute givenness of reality are unintelligible because irrelevant. We participate in the evolution of reality by every moment of conscious experience. The truth hasn't all happened yet, as Professor James says. Kant was right in a sense when he said that the understanding creates the world. But it is equally true that for any particular individual and for any particular moment of conscious experience, the high-lights of attentional consciousness are set over against a background of what, for the situation, must be taken as given—and this is the truth the metaphysical realists have built into a wall of separation between a subjective and an objective world.

These are some of the implications of the pragmatic philosophy as a doctrine of empiricism. But we maintained that it likewise represents a form of idealism, and that this is not only consistent with, but absolutely indispensable to the integrity of the empirical side of its method.

The pragmatic philosophy, by virtue of the fact that it purports to be a *philosophy,* is a form of idealism. All philosophies are idealistic in the deepest sense of the word—they are simply developed ideas of the universe. Pragmatic idealism is only a closer-knit synthesis of practise and theory than other forms of philosophy. If we define idealism as any philosophy which finds the key to the nature of reality in ideas, then pragmatism is a form of idealism, since it is itself a theory, an idea, a conception, a philosophy of experience. There is no necessary antagonism between pragmatism and idealism, since there is no necessary conflict between practise and theory. Pragmatism is not opposed to theory, but only to bad theory; it is not opposed to ideas, but only to ideas that do not work in practise; it is not opposed to ideals, but only to ideals that do not stand in organic relation to life.

The idealistic phase of pragmatism is to be found in its theory of knowledge, in its doctrine of the relation of ideas to action. Thinking, it holds, *is* action in process of transformation into more adequate action; the pragmatic philosophy is only human action or practise passing into the idea or theory phase for the sake of evolving a more adequate practise. Whether pragmatism is idealistic in either of the other two historically important senses of the word, which hold respectively that ultimate reality is mental (metaphysical idealism) and that the objective world has no existence independent of a knowing subject (epistemological idealism), is easily answered: it is not. These forms

of idealism, as Mr. Schiller and Professor James and Professor Dewey in their different ways have shown us, are simply methodological circumlocutions produced by the interposition of false issues by an aprioristic preconception.

As long as men stop their practise now and again to think, they will be idealists. As long as the process of experience is more than a mere blind rule-of-thumb accidental fumbling or slow learning by the method of trial and error, as long as human progress takes place by experiment and invention as well as by repetition and imitation, the philosophy of experience must in the deepest sense of the word be idealistic. Ideas are not copies of realities beyond experience, but are certain contents which, because of their inadequacy, are undergoing revision in that mode of consciousness which we call knowledge: and consciousness and cognition are simply names for reality when thus undergoing reorganization from within. Ideas, as Professor Dewey says, looked at negatively and in relation to the practise which is breaking down, are simply facts which have come under suspicion. Thus we say that the sun-going-around-the-earth is a mere idea because it has become doubted: we call it an illusion. Looked at positively, in relation to further practise, an idea is a plan of action; it is one part of experience used as a means of getting further experience. There is no chasm between the world of things and the world of thoughts; the world of thoughts *is* the world of things viewed *in process* of becoming something different from what they have been in relation to the needs of former practise. From this point of view there is no need for a timeless, processless, inscrutable absolute to guarantee the integrity of a subjective-objective, mind-matter, ego-alter world: the only absolute required is the concrete process of experience itself. There is no absolutely absolute absolute just as there is no absolutely relative relative. Absolute idealism and absolute scepticism are self-contradictory limiting conceptions, neither of which is true, taken by itself, but each of which is useful in refuting the other by throwing it back upon the concrete process whence it was derived and where alone it is significant.

Quite the most delightful humor of the present philosophical situation is the way in which the pragmatists in practise repudiate pragmatism as a theory, while on the other hand the pragmatic theorists fail to see their own incorrigible idealism. Rotund in the complacency with which they regard their abstract ideals, which they sentimentally revere, but never use, the actual pragmatist looks with contempt upon the theory of his own practise when some ingenuous idealist seeks to formulate it for him. For what is pragmatic theory to him who is a pragmatist in conduct? It is heresy, blasphemy, anarchy—destruction of established ideals which must be protected at all hazards from any pollution by the "given case." He does not realize that he is destroying the only theoretically sound basis of his own practise, that

his so-called ideals are simply masks to conceal the irregularity and irrationality of his practise.

But the full humor of the situation does not appear until we turn to the supposed teachers of pragmatism—the pragmatists in theory. They are not really pragmatists, most of them, but idealists. They have developed pragmatism simply as a means of realizing a new idea in philosophy which seems more valuable to them than any of the old ideals. The fact that the new ideal is not consciously present or clearly worked out, does not alter the case. The function of the philosophical pragmatist of the day is not to supplant the various forms of idealism which have held sway, but to make their ideals operative as forces in the world of actual conditions and causes. It brings ideals down to earth; it does not destroy them. The positive mission of the pragmatic theorist is to show men how to use ideals as genuine dynamic functional realities instead of sentimentally worshipping them in their inviolable isolation. Pragmatism means, not the opportunism or expediency philosophy which too often is the only working theory of the man of affairs; it finds the ideal *in* the conditions, cultivates and guides its growth *within* the given case, and formulates it by reading off the "law of the process" by which those very conditions have given rise to the given case.

Men can not get along, and remain civilized, without ideals. It is not only the lover, idolizing the object of his affection, who is actuated by ideals: the successful statesman, scientist or man of business is always an idealist. He has an insight and an outlook—a point of view—which transforms the world of facts in the midst of which he lives, from a brute mass of obstruction and baffling perplexity into a systematic scheme or plan for bringing things to pass. His scheme may be false in certain particulars, but he can no more get along without some centralizing intellectual machinery than a complex organism can get along without a central nervous system or a complex civilization without its methods of communication.

Ideals are simply codes, customs, institutions, habits undergoing reconstruction in the medium of the direct emotional appreciation and rational insight of individuals. A philosophy must at bottom be an idealism because it is a theory of human progress—it seeks to deal in idea methodically with all the conditions by which man evolves an increasingly enriched experience. But experience is not thus mediated when certain standards, relevant in some past situation, are carried over bodily and unrevised into new conditions. This is the fallacy of most of the rationalistic and absolutistic forms of idealism which have held sway. Accepted types of thought and action are imposed on a new situation, and where the new conditions do not fit the rigid framework of the old standard, effort is made to force them into conformity with it. This is the obstructive aspect of absolutism against which pragma-

tism has raised its timely protest and its demand that *all* the factors of a situation must be represented *constructively* in the result.

The pragmatic philosophy, in other words, is a functional idealism: its method is at once intrinsic or immanent and functional or organic. By saying that its method is immanent, we mean that experience must be interpreted from within. We can not jump out of our skins, as Professor James says; we can not pull ourselves up by our own bootstraps. We find ourselves in mid-stream of the Niagara of experience and may define what it is only by working back and forth within the current. "We don't know where we're going but we're on the way." If it be asked, Where does this "concrete" experience come from? the question, as Professor Dewey replies, is irrelevant. Experience does not "come from" anywhere. It *is* here. We begin with it as the reality-here-and-now. To pursue the question of the origin of experience in an absolute sense, is to seek to run out on an abstraction as if it were a tight-rope, when it has no support at the other end. "How experience became we shall never find out," writes Professor Dewey, "for the reason that experience always is. We shall never account for it by referring it to something else, for 'something else' is only for and in experience." Or, as Professor James has put it, "Though one part of our experience may lean upon another part to make it what it is in any one of several aspects in which it may be conceived, experience as a whole is self-containing and leans on nothing."

By organic or functional is meant that all distinctions in theory are true only in relation to the specific situation within which they are set up. There is no truth in general or in the abstract: there are only truths. It further means that in the case of all the dualisms of reflective thought which have occasioned so much controversy in the history of philosophy, each abstract member of the dichotomous distinction is true only in relation to the other. Does a man walk more with his left or with his right leg? asks Professor James. If he is lost in the forest in the northern hemisphere, he may be said perhaps to walk more with his right leg when he goes around in a circle to the left, but more important than the fact of inequality is the fact that he must use them both and that they must cooperate to a common end, if he is to be said to walk at all. When I follow the squirrel around the tree, do I or do I not go around the squirrel? As Professor James here, too, has pointed out, I do, and I do not, go around the squirrel according to which situation of "going around" is under discussion. As he continues, it is not particularly illuminating when you ask what o'clock it is, to be told, as the traditional metaphysician tells us, that he lives in Kensington Place.

Only by a functional interpretation of the time-honored antinomies of reflective thought is it possible to put any practical meaning into the

dualisms of actual and ideal, finite and infinite, one and the many, subject and object, mind and matter, ego and alter, reason and faith, good and evil, right and wrong, experience and reality, and the host of other antitheses which the dialectical ingenuity of sapient man has teased out of the intricate meshwork and living tissue of concrete experience.

In conclusion it should be said that, just because pragmatism is idealistic, it is not egoistic, as it has been falsely charged with being, in either the social or the ethical sense.

One of the main contentions of the pragmatists who have been quoted in the foregoing paragraphs, especially of Professor Dewey, who is its most consistent exponent on this side, is the social conditioning of consciousness and of the knowledge process by which reality is constituted in experience. This is not the place to expand upon it, but it is important to note that for the pragmatic idealist, consciousness is essentially social in its content, individuals are functions of each other, selfhood is achieved only through interaction of selves; and cognition, which is ordinarily conceived as a mental process going on in the head of some so-called individual, is a process which includes the object as well as the subject in its activity. As Professor Royce has so ably set forth, the external world is the communicable world, is socially constructed, and it may with truth be said, as a recent writer expresses it, that it is as proper to call ultimate reality a society-of-selves as to call it the absolute.

The pragmatic ethics is currently described as the art of making one's self comfortable in the long run, or, in its more cynical form, if you can't have what you want, don't want it. The reply to the implied criticism in the first formulation is that egoism is not incompatible with altruism. It is true, not only that what is good for society is good for the individual, but that what is good for the individual must in the long run be good for society. Egoism or individualism in a functional sense, which recognizes the relationship of the self to the social whole, is the very essence of progress. Egoism and altruism, like other abstractions, when taken in isolation, confute each other. An altruism which is only an excuse for trying to manage other people's affairs is not different from a self-centered egoism; while an egoism which conceives of the self so widely and so generously that it can not find happiness save through the happiness of others, is a very genuine kind of altruism. And the alternative suggested in the second formulation of the pragmatic morality is not the only one: another would be: If you can't have what you want, want it more vitally, more organically, until you get it. A pragmatic ethics refuses to believe that any craving or impulse of human nature is bad as such. There is no absolute evil. Error and evil, like truth and good, are matters of relationship; and, just as the truth is not attained until all the so-called

errors are seen in relation to each other and to the whole as partial truths, so all the so-called evil impulses of man must be represented constructively in that outcome of the moral struggle which we call the good. "Nothing succeeds like success," "It's true if it works," are phrases which are capable of an idealistic interpretation in relation to social progress as well as of an egoistic and ethically materialistic interpretation which results in anarchy.

Life is a game of skill, and pragmatism is an attempt to "play the game" as well as possible, since perforce we must play it. It *is* a philosophy of work, of practise, of labor, of the strenuous life; but it is not simply that. Since, as we have seen, it is not mere practise, but likewise a theory of practise, this brings in the other side which we have called its idealistic aspect. But pragmatism is more than either an empiricism or an idealism: it is an immediatism or mysticism in the good sense of the word—it is a philosophy of play and a branch of fine art. It provides for moral holidays; it is a philosophy of that culture which in its leisure is not idle; it finds a place for the feelings and values and ends of life as well as for conduct and ideas and the means of living. The simple life is as truly its goal as the strenuous life! The simple life!—the "last refuge of complexity!" How much effort people put forth in the endeavor to lead the simple life! It is not getting away from complexity, but controlling complexity in relation to the attainment of the values of life, that pragmatism recommends—not the simple life, but the simplified life. And among other means of the control of cultured living, a true philosophy finds its place: first, as a balance-wheel to the tangential tendencies of lopsided common sense with its uncommon stupidities and rigidities and foreshortening of view; second, as a clearing-house for balancing up the credit and debit accounts of science in relation to this great problem of the control of the conditions of living; and third, as an enhancement of the appreciation of the values of life in emotional and personal terms, by seeing all knowledge and conduct in their widest cosmic and deepest spiritual implications, and feeling with Kant and Tennyson the relation of the flower in the crannied wall of one's own door-yard to the stars above and the moral law within. This is pragmatism and this is a philosophy which must recommend itself to men and women of to-day.

THE MOVEMENT TOWARDS "PHYSIOLOGICAL" PSYCHOLOGY. II

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IV

THIS brings us at length to the true physiological line, and to the rapid assimilation of psychology to positive science. The starting point lies in that French group whom Napoleon nicknamed contemptuously, *les Idéologues:* Cabanis, de Tracy, Laromiguière, and Maine de Biran.[1] Cabanis and de Tracy were the leaders in all essentials. Their movement formed part of the mighty revolutionary upheaval. By analysis of sensations and ideas they proposed to discover a method of remoulding society, government and education for practical purposes. De Tracy (1754–1836) elaborated what Beneke would have termed the "inner" side of ideology. His noteworthy efforts lie in the fields of language, grammar and logic, of economics and government, of morals and education. Yet the influence of science upon him, as upon his fellows, produced results that should receive notice here. He anticipated Comte in the view that knowledge, properly so called, consists in an organized system of the sciences; "positive science," as he declares, and to him, more than to Comte and his pupils, we owe this term, now beatified. In the second place, and coming to the physiological reference, he was the first to recognize the importance of muscular activity as a factor in consciousness.[2] This formed his point of contact with Cabanis, who studied what Beneke would have called the "outer"—the physiological accompaniments of psychological processes.

Cabanis (1757–1808) inherited the English sensational tendencies represented in France by Condillac, but he added that acquaintance with the human body which he acquired as a physician. In his person the philosophical and physiological lines coincided. His principal work, "Rapports du Physique et du Morale de l'Homme," grew out of a series of papers read before the French Institute and published in its proceedings for 1798–99. So far as he possessed any consistent philosophical standpoint, Cabanis was a pantheist (and, in speculative physiology, therefore, a vitalist), as his posthumous "Lettres sur les Causes premières" (1824) and his discussion of the Stoics in the

[1] Cf. "Les Idéologues," Fr. Picavet (1891).
[2] *Ibid.*, pp. 377, 337 f.

"Rapports" show. Nevertheless, later materialists find warrant for their most striking metaphor in his pages. As the liver secretes bile and the kidneys urine, so the brain secretes thought; thus ran Karl Vogt's raucous challenge (1847). Cabanis employed the very phrase "secretion of thought" which, as his editor, Peisse, says, "has remained celebrated." But the classical passage, also in the "Rapports," reads as follows: "In order to arrive at a correct idea of those operations from which thought arises, we must consider the brain as a particular organ, destined specially to produce it in the same way as the stomach and the intestines are there to perform digestion, the liver to filter the bile, the parotid, maxillary and sublingual glands to prepare the salivary juice."[3] This is the clear summons to a physiological psychology. Very naturally, Cabanis aimed to supply what Condillac omitted. Condillac's sensationalism, like that of the English school, found basis in the external senses. It therefore missed those organic and internal changes which physiology alone could set forth. Cabanis, accordingly, insisted that multitudes of impressions proceed continually from the internal organs to the brain, and that the conditions of the cerebro-spinal system form a determining factor in this process. Or, to be more emphatic, as it continues to maintain its unstable equilibrium, the organism originates *vital feelings within itself*—feelings that bear no direct reference to the external world. That is, the impressions of Locke and Hume do not play upon a *tabula rasa,* but are met, and twisted, by these organic feelings. The unconscious joins up with the conscious. Of this process instinct offers a conspicuous example. Here, primordial experiences, traceable to the embryo, provide a foundation of organic sensation which (in the light of the doctrine of evolution) would explain away psychological processes as automatic—as epiphenomena of the bodily substrate. In this respect Cabanis was a prophet. Nevertheless, despite his studies of age, sex, temperament, sensibility, irritability, habit, climate, the fœtus and instinct, he fails to work through his great theme with the necessary grasp upon detail. His epoch would not let him. Yet he saw the promised land afar off. For, to him, psychology was already a natural science. It traffics with phenomena, never with metaphysical realities, and its material must be found in the relation of mental states to physiological conditions. Hampered everywhere by contemporary ignorance of nervous anatomy, he still contrived to formulate a vivid and convincing psycho-physiological *schema,* for which, we may as well confess, due praise has never reached him. Physiology passed to another land, and he fell into an oblivion rather discreditable to the historical insight of those who came to elaborate his anticipations.

Plainly a physiological psychology can not emerge in absence of a

[3] Œuvres, Vol. III., p. 159.

physiology. The numerous accessions of physiological knowledge during the last seventy years tend to obscure the unpropitious outlook at the dawn of the period. Referring to the time (1841) when he became *préparateur* to his distinguished predecessor, Magendie, at the Collège de France, Claude Bernard drew a gloomy picture.[4] The established "natural history" sciences—geology, botany, zoology—possessed fair equipment, particularly on the museum side. While chemistry, thanks doubtless, to Liebig's activity at Giessen, made rapid strides. But physiology enjoyed no such advantages, was opposed, indeed, even by a genius of the calibre of Cuvier. "So soon as an experimental physiologist was discovered he was denounced; he was given over to the reproaches of his neighbors and subjected to annoyances by the police."[5] Sir Charles Bell had intimated the contrasted functions of the anterior and posterior roots of the spinal nerves (1807), but had given no experimental proof: and Marshall Hall (1835) had discovered the reflex function of the spinal cord. But no group of investigators had arisen such as was to place Germany in the leadership. Her preeminence, unchallenged still for physiological psychology, dates from the life-work of Johannes Müller, and his profound influence, especially at Berlin, from 1833 till his death in the year before "The Origin of Species" (1859).

At this date the intellectual condition of Germany may be called unprecedented without exaggeration. And the fate reserved for unique things has overtaken it. Later men, particularly on the scientific side, have heaped on it multiplied misunderstanding or even obloquy. Little as I cling to them, I am compelled to declare that Schelling and Hegel were no day-dreamers, evolving camels from their inner self-consciousness. Both were great men, and Hegel takes his place among the few marvellous intellects of history. But both suffered from their very success. Hegel's philosophy formed the seedplot of that comparative and critical *Wissenschaft* for which human history supplies the material. As these disciplines developed, the defects of the Hegelian system became more and more irremediable. Yet, the system lacking, the sciences could not have come to birth. Schelling stood in similar case. German science from 1797, the year of the publication of his "Ideen zur einer Philosophie der Natur," till 1830 or thereby, drew inspiration from his humane, if vaulting, spirit. Alex. von Humboldt, as his biographer Bruhns points out, attempted "by means of a comprehensive collation of details, and the institution of the most searching comparisons, to give a scientific foundation to the ideal cosmology of Herder, Goethe, Schelling and their disciples." Further, Schelling stimulated Carus, the comparative anatomist: Oersted, the father of

[4] Cf. "Physiologie générale," p. 203.

[5] *Ibid., l. c.*

electro-magnetism; Kielmeyer, an anticipator of biogenesis; I. Döllinger, of Würzburg, who inoculated Von Baer with genetic ideas; Von Baer himself, who, more objectively than any other scientific man, has estimated the *germinal* significance of the *Naturphilosophie;* Liebig, the pioneer of laboratory methods in chemistry; Johannes Müller, the first main constructive power in modern physiology; Kieser, the early exponent of plant phytotemy; Schönlein and Röschlaub, leaders in the remarkable band who founded the Berlin school of medicine. Nay more, his power burst forth again, significantly for psychology, as a factor in the equipment of Fechner. Thus, like Hegel, Schelling paved the way for his own fall, by sending others to search out the secrets of nature. Accordingly, even if the vagaries of Oken disgusted many,[*] and if Steffens's analogies between the catastrophies of the human spirit and the disturbrances of the earth's crust furnished queer geology, there were no call to "swear at large," to rush around shouting "vitalism!" or otherwise to evince complete lack of the objectivity necessary to analysis of the crisis. Somnambulists haunt the fringes of all movements, but we fool ourselves when we take them for prototypes. New ideas ever were heady; this happens to be the price set upon their power to reveal unsuspected problems, as Schelling and his galaxy of scholars did.

Johannes Müller, then, found himself born into this surging age. He tended the new scientific spirit to budding, but, unlike Von Baer, he died ere it blossomed. Speaking under reservation, as an ignorant man must, I would venture to suggest that he did not enter fully into Hegel's epoch-making idea of *process.* So far as I can comprehend his activity, he was a student chiefly of the organism in gross, that is, a morphologist, more than an investigator of vital processes, a physiologist. His importance lay in his ideals more than in his results. "A profound teacher," as his pupil Helmholtz declared, he created an atmosphere which his pupils breathed, and he lives in their splended work rather than in any single achievement of his own. In essentials this atmosphere contained the modern perspective. For, although, as du Bois Reymond has recorded, he "assumed the existence of a vital force . . . which in organisms acts the part of a supreme regulator," this "force" ruled the realm of the unknown only. In all that could be mastered by contemporary methods and means Müller accepted the chemico-physical view. His studies of nutrition, animal heat, motion and reflex action, his contributions to acoustics and the phenomena of speech embody, not simply his own work, they also supply a masterly unification of previous knowledge. But, especially as concerns physiological psychology, his major result undoubtedly consisted in his doctrine of "specific energies." No matter what the stimulus, the

[*] Cf. Huxley, in the "Life of Owen," Vol. II., p. 295.

same nerve always originates the same sensation. "Müller's law of the specific energies marks an advance of the greatest importance . . . and is, in a certain sense, the empirical exposition of the theoretical discussion of Kant on the nature of the intellectual process in the human mind."[7] Of course, Müller's views drew criticism,[8] but for us now *the* point is that they started activity which, bit by bit, built physiological psychology into a science.

Fortunate in his disciples—Brücke, Helmholtz, du Bois Reymond, Ludwig, Czermak, Donders (most teachers would forego all personal glory gladly to obtain such human material)—Müller enjoyed luck in the contemporary course of events. For a science more developed and surer of itself than physiology was about to join forces with the newer branch. Magnus, his Berlin colleague in physics, became the focal point of a movement to which Mitscherlich, Liebig, Ohm, F. Neumann, and the brothers Weber all contributed, the first and last notably. The sobering drill of hard, experimental fact gained its recognition here. Or, as we say in philosophy, the prose of Kant was added to the romance of Schelling. For physiological psychology the steadying influence came most by way of Ernst Heinrich Weber, of Leipzig (1795–1878). Weber, with his younger brothers, Wilhelm and Eduard, worked from the first along distinctively modern lines. The speculative thought, prevalent in his youth, seems to have passed over his head. Exact experimental methods came naturally, as it were, to him and to his brothers. From early life they employed mechanical and mathematical analyses in dealing with physical, physiological and psychological phenomena. Kunze, Fechner's nephew and biographer, goes so far as to say, "they were among the first to raise the study of nature among Germans to the eminence occupied by the philosophers and discoveries of the Latin races."[9] Their first joint research is typical of this. In the "Wellenslehre auf Experimente begründet" they add to Chladni's acoustic theory a parallel account for light, which leads substantially to the inference of an elastic ether. Prior to this Weber had published researches on the "Comparative Anatomy of the Sympathetic Nerves" (1817) and "On the Ear and Hearing in Men and Animals" (1827). His psychological contributions appeared in Wagner's "Handwörterbuch der Physiologie," Vol. III., part 2 (1831), and in the "Archiv für anatomische Physiologie" (1835). The classical paper, "Tastsinn und Gemeingefühl," was printed in the former and published separately in 1851. Weber here applied the method of least observable differences to sensations of pressure and to the measurement of lines by the eye. These experiments resulted in

[7] "Physiol. Optik.," Helmholtz, p. 249.

[8] Cf. *Mind*, V., pp. 1 ff. (old series).

[9] "Gustav Theodor Fechner (Dr. Mises): Ein deutsches Gelehrtenleben," p. 243.

the generalization to which the name "Weber's Law," or the "Fechner-Weber Law," or the "Psycho-physical Law," has been given. Referring to this discovery, in the preface to the first great book on physiological psychology, Fechner affirms: "The empirical law which forms the principal foundation, was laid down long ago by different students in different branches, and was expressed with comparative generality by E. H. Weber, whom I would call the father of psycho-physics."[10] The law summarizes mathematically the relation between physiological stimulus and psychical sense-perception. It is based on the fact, familiar in common experience, and now authenticated by numerous observations and experiments, that the difference between two sensations bears no direct proportion to the actual difference between their stimuli. Granted that the least observable difference be a constant, then, the strength of sensations does not grow in proportion to stimulus, but much more slowly. Weber's experiments were directed towards measuring the *exact* proportions, and involved comparisons of lines by the eye, of weights and of tones. The resultant generalization has been formulated in various ways. The most direct are as follows: "In order that the intensity of a sensation may increase in arithmetical progression, the stimulus must increase in geometrical progression"; or, as put more briefly by Fechner, "the sensation increases as the logarithm of the stimulus"; or, as Delboeuf has it, "the smallest perceptible difference between two excitations of the same nature is always due to a real difference which grows proportionately to the excitations themselves." Like all laws, so-called, this one is an abstraction from experience. Consequently, it has been subjected to various interpretations, has been transformed and criticized, and even denied. Again, like all laws, so-called (*e. g.*, Boyle's law), it holds good only within limits, and round this aspect of the matter multitudinous experiments cluster. Space forbids more than a reference to easily accessible literature.[11] Whatever psychological experts may consider to be the present status of the conclusion, Weber's withers are unwrung. His crowning achievement was to have shown that measurements and mathematical methods *can* be applied in this region of experience. He thus served himself the founder of the Leipzig line, the torch passing from him to Lotze, to Fechner, and finally to Wundt.

As at the beginning of modern European thought, in Descartes, Spinoza, and Leibniz, so here in the Leipzig men, philosophical insight

[10] "Elemente der Psychophysik," preface, p. v.

[11] "German Psychology of To-day," Th. Ribot (where Delboeuf's researches are given). "The Human Mind," Sully, Vol. I.; article "Weber's Law" in the "Encyc. Britannica"; "Principles of Psychology," Wm. James, Vol. I. (a most unfavorable critique); "Elements of Physiological Psychology," Ladd; "Human and Animal Psychology," Wundt, Lectures II., III. and IV.; "Outlines of Psychology," Külpe.

and power were joined to scientific competence. I, therefore, leave them for a moment to take a glimpse—it can be no more—at the strictly scientific interest as we see it illustrated in Johannes Müller's greatest pupil, Helmholtz (1821–1894).

Helmholtz ranks not simply with the foremost scientific intellects of the nineteenth century but with the master minds of all time. His range, grasp and insight combined to render him monumental. A contributor to at least eight sciences—physics, physiology, mathematical physics, meteorology, medicine, chemistry, anatomy and esthetics, in three of them he stands high among the foremost. More than this, as Volkmann has recalled, "one of his chief merits was to establish a harmony between the vast accumulation of facts that characterized the period comprehending the middle of this century and the more theoretical studies."[12] Besides, he possessed unusual manipulative skill, his inventions of the ophthalmoscope and ophthalmometer alone would have assured any ordinary reputation. Above all, he was a humanist, being an accomplished musician, an art critic, and acquainted with the trend of philosophical thought. His discoveries of classical grade amaze one by their thoroughness and versatility. The conservation of energy; the mechanism of the lens of the eye in relation to accommodation; the movements of the eyeballs with the attendant problems of binocular and stereoscopic vision; the profoundest questions of hydrodynamics, thermodynamics and electrodynamics, the last culminating in the revelations of his favorite pupil, Heinrich Hertz; the axioms of geometry; the dark places of meteorology; the deeps of physiological optics and of mathematical physics, all bear witness to his profound, masculine and subtle intellect. But, for our present study, the palm must go to his long struggle with the difficulties of sensation and perception. These absorbed his principal attention from 1852 till 1867 and, in a lesser degree, till his death. He laid the foundation characteristically by his inquiries into the rate of nervous impulse in the motor and sensory nerves, about 1850, and his first paper, on sensation proper, followed in 1852. These labors were crowned magnificently by the publication, in 1863, of his "Sensations of Tone," and, in 1867, of his "Physiological Optics"—masterpieces both. The former, which involved the most complicated research, has earned the title, "the *Principia* of acoustics," and must be studied long to be appreciated. For, it not only ranged over the entire subject but, incidentally, raised important problems that belong elsewhere, especially to the domains of phonology and esthetics. Questions about the quality of the human voice and the absolute pitch of vowel sounds lead us away from the physical and the physiological laboratory to a very different environment. Similarly, the "Physiological Optics," with

[12] "Hermann v. Helmholtz," J. G. McKendrick, p. 284.

the Young-Helmholtz theory of color, presents investigations about which psychologists are bound to trouble for many a day.

Thus, the significance of Helmholtz's career may be traced to his combination of the mathematical and exact-scientific with the humanistic interest, a union to which we may attribute our greatest advances alike in science and in intellectual insight. And this fitted him rarely to execute work of abiding value for physiological psychology. No one has contrived to reach better results in those unplumbed reaches of experience where the joint action of body and mind can be studied with a measure of success. Proceeding from the theory of "specific energy" of his master Müller, he wrought it out in detail, eminently for the mechanism of sight and hearing, by experimental methods and by mathematico-physical analyses. Upon the romantic interest in nature stimulated by Schelling he superimposed the critical processes of Kant, armed with all the resources of the most delicate apparatus and rigid analytic procedure. This coalition of endowment and outlook continued in the three leaders who were destined to build psychology into an independent science—Lotze, Fechner and Wundt. To them we shall turn next.

A PHYSIOLOGICAL PROBLEM: ENZYMES

By ORVILLE HARRY BROWN, Ph.D., M.D.

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THE question of enzymes is one of fascinating interest to the biologist. There is more or less of a mystical atmosphere surrounding these unknown ever-present bodies in all living organisms, on account of the difficulty in effecting their isolation, and in regard to the method in which they perform their function. The study of enzymes has been pursued with much vigor for years by eminent investigators of the biological sciences, and yet their exact nature is almost as little understood to-day as ever. No enzyme has been absolutely isolated, and consequently the chemical constitution of these principles is yet a matter of conjecture. We can, however, unerringly detect their presence, both qualitatively and quantitatively.

The terms enzyme and ferment as used to-day are practically synonymous. The latter term is doubtless the more familiar of the two to the laity. A classical example of fermentation is the changing of sugar, by means of yeast, to alcohol and carbonic acid gas. The yeast is necessary to this process, in so far as it elaborates the active agent—enzyme, or ferment—which is essential. The yeast, more properly according to our former conception, than now, is spoken of as an organized ferment. This was on account of the supposition that the yeast itself was the ferment. It has only recently been shown that a substance can be extracted from the yeast cell, which brings about the process, spoken of as fermentation. In contradistinction to the organized ferments there were the unorganized ferments, as, for example, the enzymes of the alimentary canal, which were capable of bringing about digestion as well outside of the body in a test beaker, as in their normal habitat, the stomach and intestines. The separation of a material from the yeast cell, which still possessed its activity made obsolete the classification of unorganized and organized ferments. The agents which were formerly classified under the two heads, although differing in characteristics, are alike in that both are definite chemical substances secreted or manufactured by cells—a single-celled organism in one case and a multicellular in the other. Many bacteria were formerly believed to belong to the same class as the yeast, and thought to possess a fermentative function; now it is known that the bacteria elaborate a substance which has the enzymotic properties.

The physiologist defines an enzyme as a body, which, remaining

unaltered itself, accelerates a chemical reaction, otherwise going on very slowly. To elucidate with an example: fat is a chemical union of two compounds, one of which is called a fatty acid, and the other an alcohol. Fat, in the absence of a fat splitting enzyme, yields very small quantities of these two substances in the course of a long time. But, in the presence of a proper enzyme the fat yields considerable quantities of fatty acid and alcohol in a comparatively short time. The rapidity of the splitting is directly proportional to the amount of the enzyme added. A small amount of the enzyme will decompose just as much of the fat as a large quantity will, but a longer period of time is required. A quantity of the enzyme may be used over and over again for splitting any amount of fat, unless it is destroyed by bacteria, heat, chemicals, or some other deleterious agent.

When fat and an enzyme are placed in a test tube together, not all the fat is changed into its component parts. The reaction proceeds until more than half the fat is decomposed. Then there is a reversal of the chemical reaction. Fat is reformed from the fatty acid and alcohol; the splitting process proceeds very slowly if at all. The fat formation goes on as the predominant process in the tube until an excess of fat is formed, when a reversal again occurs, and fat decomposition becomes the chief reaction in the test tube. The alternate breaking down and building up goes on indefinitely, like the swinging back and forth of a pendulum. The sweep of the pendulum when first started may be broad, but if allowed to swing uninterruptedly, there is a gradual diminution of the distance traversed until the pendulum eventually comes to a standstill. Thus it is with the chemical reaction. This power of an enzyme to carry a chemical reaction in either direction is spoken of as the reversibility of enzymes. This has not been demonstrated to be true of all these bodies, but the physiologist delights in the speculation that it is; and many are the problems planned to demonstrate this characteristic in this or that enzyme.

Enzymes have important functions to perform in both animal and plant economy. Practically all of the chemical reactions, normally occurring in life processes, are believed to be aided by ferments. The distribution of these bodies in an organism is general. In man they are found, not only in the alimentary canal, but in the blood and lymph and presumably every cell of the body. The ferments of the alimentary canal are there for the purpose of splitting the food stuffs into their components, which are more readily absorbable than the original materials. Those of the liquids and cells of the body reform and build up the food elements into the vital tissues or protoplasm of the organism.

Another process in which enzymes play an omnipotent part is that of respiration. The oxidation of the protoplasmic constituents, from

which the heat and energy originate, and upon which life is so alarmingly dependent—going on, not chiefly in the lungs or blood, but in every cell of the body, is responsible to an enzyme, or catalase, known as an oxidase. The result of these elements, which is the bringing about of the union of oxygen with the tissue, is perfectly well known, but the chemical nature and the physical characteristics of the oxidases, are problems for speculation.

The enzymes in plant cells are similar at least in action to the corresponding ones of animals; but, in addition to those possessed by animals, plants have ferments which enable them, in the sunlight, to use carbonic acid gas in building up some of its cell constituents.

The method used in the laboratory for demonstrating the presence of an enzyme is very simple. The tissue to be examined is finely minced and ground up in a mortar. In order to facilitate the division of the cells, sand may be used in the grinding. The pulverized mass is then mixed with water or a dilute salt solution, which dissolves the enzyme. To find out what the nature of the enzyme may be, a small amount of the solution just prepared above, free of residue, is added to a solution of a substance, as starch, fat, or proteid, which an enzyme may decompose. After the course of a few hours the mixture is tested for the splitting products of the respective substance added. If such be found and none were in either solution when kept separate, it may be safely concluded that an enzyme has been discovered in the tissues examined. Very likely it can be demonstrated that the tissue contains more than one ferment, by showing that the tissue extract will split more than one class of substances.

It has been but recently discovered that enzymes or, better, proenzymes have an interaction. The pure secretion from the pancreas does not digest proteids. The unadulterated juices from the intestinal wall do not split up proteids. But a mixture of the two secretions possesses marked proteolytic powers. This phenomenon has also been observed with other ferments.

It has been known for years that certain finely divided metals, like silver, platinum, gold and others, possess the property of accelerating some of the reactions of, or chemical changes in, inorganic chemistry. As an example—if any one of the above metals be added to a solution of hydrogen dioxide, the compound is decomposed into its constituents, water and oxygen. It remained, however, till recent years for a young man working in the physiological laboratory of one of our great universities to show that these finely divided metals, elements of the inorganic world, could perform the function of a body ferment. Finely powdered platinum prepared by precipitation—known as platinum black—when added to a simple fat, decomposes it, in the same manner as a body enzyme would do. The metal has practically all the char-

acteristics of an organic enzyme. It digests the fat; it rebuilds fat from the component parts, *i. e.,* its action is reversible; it is affected similarly by temperature changes and chemicals.

Another parallelism exists between the "vital" and inorganic phenomena, in the action of the salivary juice and acids on starch. The starch is to a greater or less extent digested in the mouth by virtue of a starch-splitting enzyme of the saliva. The same thing occurs if the starch and saliva are put together in a test tube. Acids will also digest starch. There is one marked difference, however, between the two. Enzymes act best at body temperature or a little above, while acids require boiling for their optimum action.

The temperature at which ferments act best is usually a little above the temperature of the body to which they belong. The optimum temperature for the action of enzymes of cold-blooded animals is below that for warm-blooded animals. A rise of twenty or thirty degrees above the optimum temperature destroys the ferments. A lowering of the temperature unless to the extreme does not kill; it only inhibits. The enzymes regain their function when the temperature returns to normal.

Many drugs have a very decided influence upon the fermentative processes. Of recent years this problem has occupied the mind and time of a number of physiologists. It is evident that this is a question of vital importance, on account of the general distribution of enzymes in the body, and the common introduction of drugs into the body. Very much too little is known, by even the scientific physician of to-day, regarding the action of drugs on the enzymes of the body. Some chemicals when present with the enzyme increase its power to do work; others decrease its power; and others stop it entirely. The concentration of the chemicals is of paramount importance. Most chemicals in concentrated solutions entirely prevent the action of ferments. On dilution the inhibitory power of the solutions decreases. In moderate concentrations some inhibit, more or less, and some stimulate, more or less. Both these processes usually decrease as the concentration of the respective solutions decrease. In some cases an effect may be noted in even very dilute solutions; a good example of such a solution is hydrocyanic acid.

If the author has been successful in the presentation of this subject, the reader should be impressed with the importance of the problem. The intimate relationship of enzymes with the vital processes renders an extensive knowledge of these bodies fundamental in the research into the phenomena of life.

NEEDED: A SYSTEM OF AQUATIC FARMING

By Professor HERBERT OSBORN

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THERE is a natural resource available in many parts of the country, indeed, on a large number of farms or in larger unused tracts of the entire Atlantic and Mississippi Valley region, that is not only almost wholly neglected, but the neglect of which involves a number of phases of economic loss. This loss becomes more serious and the reparation the more difficult as time passes, and hence a note of warning and appeal seems justified.

The present tendency is to reduce not only all accessible forest areas to ordinary farm cultivation, but by drainage of all possible swamp areas to still further increase the area for ordinary tillage and to decrease those tracts which have in some degree the function of holding and regulating the outflow of our rainfall.

Without attempting to discuss all the economic problems connected with this phase of the subject, we may note that it affects the constancy of water level over considerable areas, the flow of streams with its bearings on flood disasters and navigation, but perhaps more vitally the carriage of fertility from the farming regions to the sea, where, if it ever becomes available as a human resource, it is so remotely advantageous to the farm or to the nation that it must be counted an economic loss.

The assumption seems to have been, based, doubtless, on our knowledge of but one kind of farming, that every bit of land not under ordinary farm culture was a loss, and therefore to be transformed as rapidly as possible to cultivated fields. To this end, forests have been felled, and lowland swamps and marshes, even including many extensive and valuable bodies of shallow water, have been drained. This means that instead of acting as natural reservoirs and conservators of moisture and fertility, their surplus moisture content has been discharged as rapidly as possible into the rivers and so on to the seas.

Before making some suggestions as to systems of farming by which it seems possible to avoid this waste, and, on the other hand, to develop some most productive sources of wealth, it will be in place to call attention to the capacity for production resident in every permanent body of water.

Every one is familiar with the rank growth of swamps and lowlands and the most superficial observation will reveal the enormous masses of

plant life growing in bodies of still water, or even in running water where the bottom will permit the rooting of the plant. But in addition to this evident growth there is an enormous development of life, microscopic or transparent and invisible except when collected and studied by proper methods, which, in rapidity of growth and amount of mass may far outclass the visible portion. Some of this becomes apparent as green scum or as floating masses when its growth exceeds the capacity of the aquatic animals to consume it. Sometimes these minute algæ become a great source of annoyance in water supplies if for any reason their multiplication is unchecked, since they give offensive odors and taste to the water.

It has been estimated that the rate of development in some of these organisms is such that the possible progeny of one individual would suffice to fill all the waters of the globe in less than a week.

This is significant to us here simply as showing the enormous possibility of these organisms in utilizing water and air in the formation of vegetable substance, which substance may, with proper utilization, be transformed into fertilizing agents for the production of valuable plant crops or into animals having direct commercial value. To understand this process, let us consider for a moment the relations existing among aquatic organisms. The algæ may be considered among the more simple and these develop with only water and air or the other inorganic contents of water, but they furnish food for an innumerable host of microscopic animals such as amœbæ, rotifers, etc., and these in turn are fed upon by others, such as microscopic crustacea, which again form an important part in the diet of young fishes. These, when grown, or after furnishing the basis of food for other larger species, may reach our tables as human food. This, however, is but one line of transformation, as we have fishes of very different habits utilizing different kinds of aquatic life as food.

Where the life taken from the water does not balance the production, or where this product is not drained off into the sea, the accumulation of organic débris forms at the bottom a mass of richest organic matter, which by its decomposition may in a large part result in marsh gas, and in this form escape into the air.

Having indicated the possibility of an unworked phase of agriculture, or *aquaculture*, let us now turn to some of the possible lines of development in this field.

We have in America practically no established system of cropping our water areas. It is true that some progress has been made in the sponge farming of Florida, and oyster farming in Rhode Island, Connecticut, Virginia, North Carolina and Louisiana, but even these need further development to utilize the natural possibilities.

But so far as fresh-water culture goes, there is scarcely a begin-

ning. Something has been accomplished in fish culture in some sections, but even here the full utilization of the resources of a body of water are but poorly accomplished. A few sporadic efforts have been made here and there in the culture of frogs and turtles, but how many of them with such attention to the subject as to warrant the term culture? In fact, these efforts have often resulted in failure and their projectors looked upon as visionaries, worthy the contempt of the hero in the "Virginian."

The farmer who drains and cultivates an acre of swampy land on his farm gains that much additional space for his ordinary culture and for a time at least it may be unusually productive as it contains the accumulated organic débris of years, but would it not be far greater wisdom to dredge out occasionally a portion of this accumulation to spread upon the higher ground and keep the acre as a source of fertilizing material for the years to come. This seems all the more desirable when it is remembered that this basin must collect quantities of the finest and most fertile parts of the soil washed from the higher ground. Moreover, I hope to show that there is good reason to expect that the acre can be made so productive over and above this function of conserving fertility that it will be worth more in water than it could be as cultivated land.

What is needed in the matter of utilization of our great tracts of marshy or swampy land is some such systematic study and the development of some such adapted system as is in progress of development in the systems of "dry farming" in the arid or semi-arid regions of the west—a system which will intelligently conserve and utilize our heritage of water, not throw it ignorantly away and reduce our uplands to a condition of sterility.

Frog farms, turtle farms, fish farms by themselves might be put in the same category as skunk farms and fox farms; useful to utilize certain minor tracts of otherwise worthless land, but what is needed, if any general good is to follow, is a rational system applicable to the treatment of all tracts of level swampy land, especially those at the head waters of the great river systems and in the coastal swamps of the Great Lakes and river deltas—in fact, to all areas where a fairly constant water level is possible.

Possible Crops

It is evident that in the nature of things wherever private ownership exists, or is possible, the effort inevitably will be toward gaining the largest immediate return from any such area, and the only hope of preserving these swampy tracts as reservoirs of water will be to hold them as public reservations or to devise some system of production which will make them more profitable with the water retained than they

can be with the water removed. Hence an extended and careful study of the crops available for culture in such tracts becomes a pressing necessity. Such a study will of necessity involve years of investigation, both of the practises in countries where some such systems exist and of possibilities under our own conditions of available crops, markets, machinery, etc.

A short résumé, however, of some of the crops which already have some claim to notice and those which give promise of availability will help to show the possibility and practicability of such a system.

Among the plant crops which may be mentioned are water cress, which is already an article of considerable commercial value, but probably much less used in this country than elsewhere and doubtless much less than if the supply were increased. Methods of its culture are, of course, well known and would be simply a matter of adaptation to particular areas. The cranberry is also a well-known crop, adapted to bog or swamp conditions and for which there is unlimited demand.

Some of the marsh grasses, cat tails, rushes and other plants make a most abundant growth, and in association with other crops could no doubt be cultivated to good advantage. The basket willows are of great value and are used extensively in the manufacture of baskets, an industry which is capable of much expansion. The pond lily surely offers an opportunity for a most valuable aquatic crop, if systematically cultivated and harvested, especially in the vicinity of large cities and popular excursion resorts.

We may mention, also, the development of the industry, based on the slough-grasses of the northwest, including the manufacture of binding twine, mattings or carpetings and furniture. This utilizes an extensive area of wet land, not available for other crops, and which, if retained for this crop, doubtless could be utilized also in the culture of some other more distinctly aquatic crop. Other fiber plants are a possibility.

Of animal crops which are already known, fish culture is the most extended, but in general this is not reduced to a systematic farming basis. I can recall the furore created some twenty-five or thirty years ago, in connection with the introduction and proposed production of carp, but so far the carp industry in this country is mainly confined to that grown without attention, and gathered indiscriminately by fishermen without reference to any private rights. The market for this fish has, however, greatly increased and in centers where there is a large European population, as in New York City or Chicago, immense quantities are sold, and it is claimed that these people prefer carp to other fish which are greater favorites with American tastes. Under other names carp are sold to a considerable extent in our markets and, under such disguises as "smoked sturgeon," may pass as a distinct

delicacy. This fish, on account of capacity for rapid multiplication and growth in restricted quarters and in ponds with abundant vegetation, is, perhaps, one of the most available for systematic cultivation. Other fishes, such as catfish and some of the species of bass, could be utilized in certain situations to good advantage.

While frogs have not been, as yet, a very common article on our markets, I do not know that the market has ever been over-stocked, and in the vicinity of large cities it would seem that a much larger quantity could be disposed of. As it is, immense numbers are utilized in the laboratories of schools and colleges, this demand being met for the most part by the capture of frogs in natural ponds. Crayfishes have not attained any special market value in the majority of markets, but I am told that they are sold to a great extent in New York City, and I see no reason why they should not be used as much as shrimp. Terrapin and no doubt other species of turtles could be marketed in much greater numbers than they are at present if their cultivation were systematized and markets properly handled. Both ducks and geese, while reared, so far as domestic species are concerned, very largely on land, would no doubt thrive better and get the best part of their growth on aquatic plants which form the greater part of their native food. They could be readily cultivated in connection with other crops.

The shells of fresh-water clams have been the basis for the establishment of some extensive button factories and the pearls that they produce have furnished a livelihood to a considerable number of individuals. But it is said that many of the factories have had to close on account of the exhaustion of the clams in adjacent streams. Doubtless, some reasonable system of gathering the shells or providing for the propagation and growth of successive generations would easily make this a permanent crop in suitable waters.

Alligator hides have a high commercial value and are all too scarce, with good prospect of disappearance from the extermination of the ungainly animal that produces them. I do not know that an alligator farm, fenced out in a suitable swamp or bayou, would be a commercial success, but it would seem well worth while to experiment in some of the swampy wastes in the domain of this prince of reptiles.

It may be somewhat remote, but it seems conceivable that it would be possible to utilize some fur-bearing animals in this direction, as, for instance: the beaver, muskrat, and possibly the otter, as these animals could certainly be colonized in suitable localities where an abundant water supply at a fairly constant level is available. As to possibilities of securing any regular crop from such animals, we have little data to guide us, but we know that under natural conditions they multiply at a fairly rapid rate. Muskrats in some localities are caught and marketed for food as well as for the skins.

With regard to salt or brackish water crops, we have already a good deal of knowledge, and with some animals and for certain localities quite thoroughly organized systems of cropping have been established; for instance, the sponge farms in Florida and oyster farming in some of the Atlantic states. The latter, however, are by no means so fully regulated as to secure the best results, as is shown by the exhaustive discussion of the subject by Professor Brooks. His estimate that the product from Chesapeake Bay of $2,000,000 annually, could and should be increased to $60,000,000, has, I believe, never been challenged, and indicates the possibilities. There are other marine forms like lobster, crab, shrimp and turtles which would lend themselves to similar definite systems of cultivation, and in fact a study of the basis for such systems has been in progress in the Bureau of Fisheries for many years past. It is necessary, however, that the results be carried into definite regulations or embodied in appropriate legislation in order to secure perpetuity in the crops and the most profitable returns.

In many instances, in both salt and fresh water areas, there will need to be entirely new legislative enactments providing for the regulations of water areas in which certain more or less sedentary animals may be cultivated. For such as migrate freely in the open waters there is perhaps no better policy than to permit capture by any individual under such restrictions as to season and quantity as may serve to protect the future supply. If animals have a fixed habitat and are capable of artificial propagation or culture, there is no logical reason why a person who plants and cares for such a crop should not be protected in the right to harvest it. Under existing laws, however, there is great difficulty in securing such rights, as all waters which have any connection with navigable streams or lakes are assumed to be public property. It would be entirely practicable, however, to guard the rights of property in the bottoms or shores without interfering in their public use for navigation, pleasure or even for fishing for such forms as are migratory. These are questions, however, which can be worked out when once the advantages of systematic cropping of water areas is fully recognized.

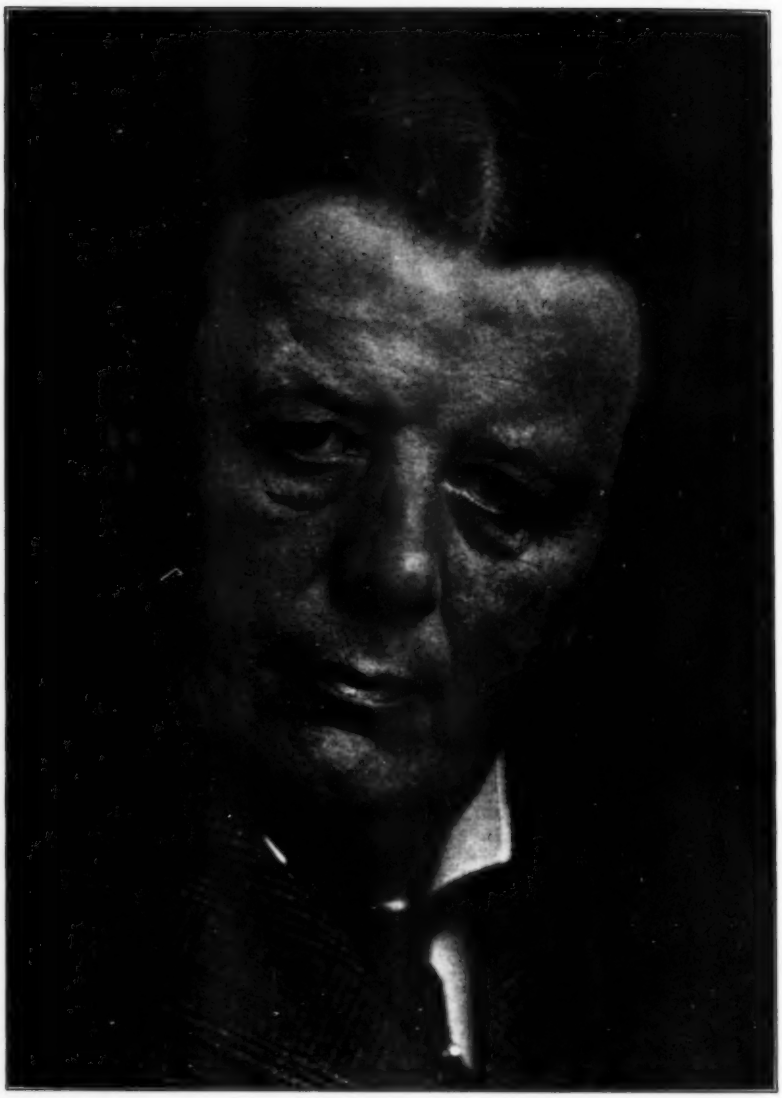
Aside from measures which utilize existing areas of swamp it appears to me that great advancement may be made in the combination of certain land and water crops, for instance, in a tract of marshy land having practically a constant level it would seem possible to alternate strips of land and water by the use of suitable dredging appliances, the land portion being utilized for the cultivation of such intensive crops as celery, asparagus, onions, strawberries, blackberries, etc., the fertility being maintained by adding dredged materials from the bottom of adjacent water strips. The water strips could then be utilized in the culture of such aquatic forms as fish, frogs, clams, turtles, ducks, etc.,

as may have the greatest value in the particular localities. By these methods we should avoid the loss incident upon constant drainage of water, secure an unfailing irrigation for crops cultivated in the land portion, secure a valuable source of fertility, and at the same time a valuable aquatic crop. Systems of this character, however, would be gradually developed and modified to suit conditions of particular localities.

A recent number of the *National Geographic Magazine* gives the areas of swamp lands in the United States (not including Alaska) at sixty millions of acres, almost entirely in the humid regions of the Atlantic slope and the Mississippi Valley.

A bulletin issued later by the U. S. Department of Agriculture gives an estimate of 77,000,000 of acres for swamp and overflowed lands and claims a possible reclamation of practically this entire area.

Both of these authors put great stress upon the wealth to be gained by the drainage of this area, and discuss some of the great national and state projects already in view, but no hint is given by either that any part of this vast area could be put to useful service except by disposing of the water.



SIR EDWIN RAY LANKESTER
Who has recently retired from the directorship of the British Museum of Natural History

THE PROGRESS OF SCIENCE

ADMINISTRATIVE METHODS IN AMERICAN UNIVERSITIES

RECENT events at Syracuse, Cincinnati and Oklahoma direct attention to the anomalous conditions of university control that obtain in this country. Elsewhere throughout the world the university is a republic of scholars, administered by them. Here it is a business corporation. The ultimate control is lodged in a board of absentee trustees, whose chief duty is the election of a president. The qualifications most regarded in the president are the ability to get money for the institution and a good presence at public functions; but he is expected to "run" the university. The professors and instructors are employed "at the pleasure of the trustees," and so long as the president maintains his position this means at his pleasure. Advances in salary or position, appropriations for apparatus, etc., are subject to the same pleasure. In larger institutions the department-store system naturally grows up. Deans and heads of departments are responsible to the president, and their subordinates are responsible to them.

As a matter of fact, men are not dominated by governments and laws, but conversely. In a great university, such as Harvard, courtesy and consideration do not fail. In the smaller colleges, there is the spirit of the family. So long as the best men are found at our colleges and universities, it may not matter greatly under what system of academic government they live. But there is real danger that the existing system may prove repulsive to men of the highest intelligence and character, and that mediocrity and time-serving may be developed, where we need the most vigorous ability and independence. Then we have occasional academic scandals which exhibit the seamy side of the system.

At Syracuse University the chancellor did not like the dean of the School of Applied Science, and has dismissed him, giving no grounds except that he had been a disappointment to the administration. However this may be, it appears that the dean has conducted the affairs of his school with skill, and has the sympathies of his colleagues at Syracuse and in the engineering profession, of the students and the alumni. A competent engineer can earn far more by practising his profession than as a professor, and the Syracuse dean has not been forced to sacrifice his independence to feed his children. He has consequently conducted a good public fight, which will doubtless lead to an improvement of affairs at Syracuse and elsewhere. The Syracuse chancellor has written: "Our professors have nothing to do with the hiring, continuing or dismissing of professors and students." But when Syracuse recently needed a professor of botany, men looked askance at the position, and the same thing will happen now when the deanship of the school of engineering must be filled. Neither the largest stadium in the world, nor a chancellor who is a methodist orator, nor a president of a board of trustees, whose corporation controls the kerosine of the country, suffices to make a university.

At the University of Cincinnati there was a few years ago a deplorable state of affairs. A president was brought there to dismiss a large part of the faculty and then he was in turn dismissed. Now the head of the de-

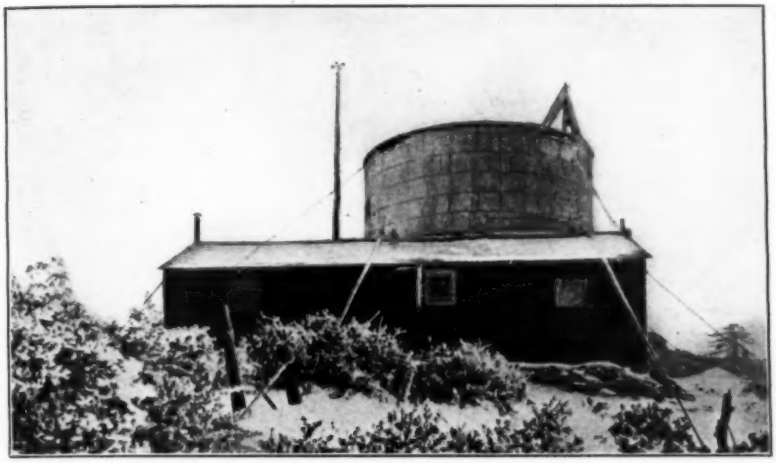
partment of philosophy has been dismissed because his family relations are not approved. It is not alleged that he is immoral, and it is admitted that he is a good teacher and an able investigator, but his conduct and opinions are said to be subversive of the family. Whatever may be the merits of the case, the administrative methods do not show to advantage.

In the new state of Oklahoma "the best constitution in the world" has not provided an ideal educational system. Indeed the conditions approach *opera bouffe* too nearly to be taken quite seriously. The head of the state university, the heads of the normal schools and of other institutions have been dismissed and supplanted by southern democrats. At the university the question appears to be not whether a professor is an able teacher and investigator, but whether he is a good southern methodist and democrat, who does not dance. Such conditions are transient. The danger is that methods which can not be approved in politics and business may obtain such footing in our universities that they will no longer be centers of democratic individualism and of intellectual and moral leadership.

THE BOYDEN DEPARTMENT OF THE HARVARD COLLEGE OBSERVATORY

URIAH A. BOYDEN, a Boston inventor and engineer who died in 1879, bequeathed property valued at over $230,000 for "the establishment and maintenance of an astronomical observatory on some mountain peak at such an elevation as to be free, so far as practicable, from the impediments to accurate observations which occur in the observatories now existing, owing to atmospheric influences." The fund was transferred by the trustees named in the will to the Harvard College Observatory, which carried out the provisions by the establishment of the Arequippa Observatory in Peru. An illustrated account of this mountain observatory and of the researches that have been undertaken there was contributed to a recent volume of the MONTHLY by the director, Professor Solon I. Bailey. Prior to the foundation of the Arequippa Observatory in 1891, several expeditions were sent out to determine the conditions that would best fulfil the terms of Mr. Boyden's will, and an account of this preliminary work has just been published in "The Annals of the Harvard College

STATION AT PIKE'S PEAK.



STATION AT MT. WILSON.

Observatory,' by Professor William H. Pickering.

The first expedition was to the summit of Pikes Peak, in 1887, where at an altitude of 14,200 feet, there was a stone hut erected by the U. S. Signal Service. Observations were made for a month, and it was concluded that altitude was not as important a factor in "the seeing" as dryness. In the following year an expedition went to California and erected a pier and a building with a revolving drum on Mt. Wilson at an altitude of 5,700 feet. This observatory was occupied for more than a year, and the definition was found to be good. There was, however, some question as to the title of the land and there were advantages in selecting a location for the observation of southern stars. As Mr. Bailey had reported favorably on the Peruvian climate, the next expedition was sent there, and the Mt. Wilson site was abandoned. It has since been occupied by the buildings and fine instruments of the Solar Observatory of the Carnegie Institution.

STATION AT JAMAICA.

The expedition to Peru arrived in Arequippa at the beginning of 1891, and a site for the observatory was selected on the crest of a ridge about 300 feet above the city. Here was erected an observatory in which there have been carried forward under the direction of Professor Bailey important observations on the southern stars.

After working in the observatory established by Professor Lowell in Arizona, Professor W. H. Pickering concluded that neither dryness nor altitude is the important factor affecting the quality of the seeing, and, in order to study the problem further, an expedition to Jamaica was undertaken in 1899, where observations were made at several stations from the sea-level to an altitude of 2,300 feet. In a second Jamaica expedition the following year a horizontal telescope, with an 18-inch mirror and 15-inch lens, was erected at Mandeville.

Professor Pickering concludes that elevation above the sea-level gives somewhat better definition, especially towards the horizon, and avoids dust and haze. A dry climate has advantages in its freedom from dew, cloud and fog, but does not give better definition than one that is moist. A low latitude has three advantages: The definition is better, the bodies to be observed pass near the zenith and a larger portion of the heavens is brought into view.

THE HANOVER MEETING OF THE AMERICAN ASSOCIATION

On the invitation of Dartmouth College the American Association for the Advancement of Science will hold a special meeting at Hanover, N. H., from June 29 to July 3. The American Physical Society and the Geological Society of America will meet with the association, and regular programs will be arranged only in physics and in geology. There will, however, be public lectures and numerous interesting excursions, and those able to attend may look forward to a pleasant visit to a typical New England college under the most favorable conditions. The railways offer rates of a fare and a third on the certificate plan, and excellent local arrangements are assured for the entertainment of visitors.

Many members regret the transfer of the annual meeting of the association from the summer to the winter. It is certainly true that the large meetings in a city are likely to sacrifice the social pleasures to business efficiency and to neglect one of the main objects of the association—the diffusion of science. A meeting such as this at Hanover should be attractive to those who wish to meet their colleagues amid pleasant surroundings, and to those not professionally engaged in scientific work but interested in it. Men and women of this class are especially welcomed to the present summer meeting and may feel free to attend without being elected in advance to membership. Those who go are certain to find the meeting both pleasant and useful.

SCIENTIFIC ITEMS

We record with regret the deaths of Dr. Heinrich Maschke, professor of mathematics in the University of Chicago; of M. Albert de Lapparent, the eminent French geologist; of Dr. K. Möbius, professor of zoology at Berlin, and of Dr. Pierre Jacques Antoine Béchamp, eminent for his researches in organic chemistry.

The house of representatives concurring with the senate and by a unanimous vote, has granted an annuity for life of $125 a month to the widows of the late Major James Carroll, surgeon, U. S. army, and the late acting assistant surgeon, Jesse W. Lazear, whose lives were sacrificed in the study of yellow fever in Cuba.